APRIL 1948

Public Works Magazine

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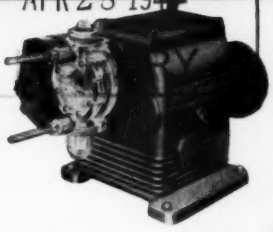
Safety in Airport Design
Waste Treatment Pilot Plant

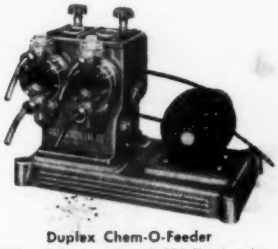
UNIVERSITY
APR 2 3 194

CHEMICAL FEEDERS FOR WATER AND SEWAGE TREATMENT

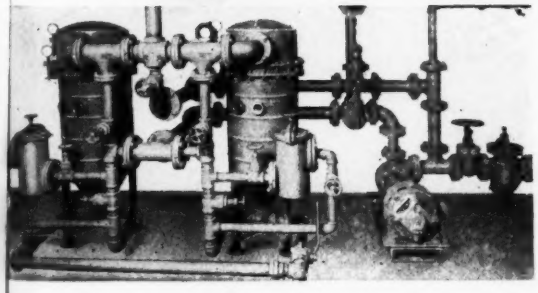
DIAPHRAGM and PLUNGER TYPE LIQUID PROPORTIONING PUMPS.
MOTOR DRIVEN and HYDRAULICALLY OPERATED MODELS.
MANUALLY ADJUSTABLE and AUTOMATIC PROPORTIONAL UNITS.
DESIGNS FOR HIGH OR LOW PRESSURE.



Heavy Duty Chem-O-Feeder
0-8 gal./hr. 0-100 lbs./sq. in.

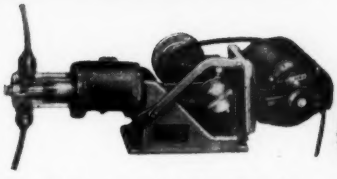


Duplex Chem-O-Feeder
0-16 gal./hr. 0-100 lbs./sq. in.

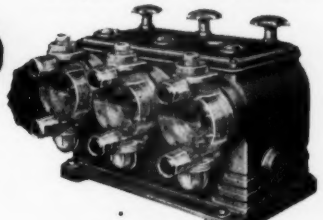


UR-O-CEL DIATOMACEOUS EARTH FILTER

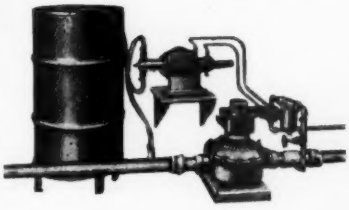
Proportioneers% new Pur-O-Cel Diatomaceous Earth Filter s outstanding advantages: It utilizes thin mats of interlaced rticles of diatomaceous earth instead of the conventional nd filter bed and produces unusually clean, brilliant water en at rapid flow rates. Filtering efficiency is so high that noebic dysentery cysts and many bacteria are removed. The ter is exceptionally compact and easy to operate. With r-O-Cel, filtering becomes a simple, mechanical operation. Write for Bulletin 1550.



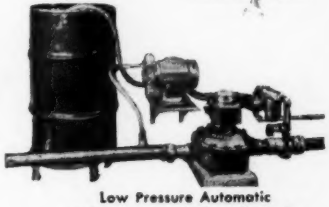
High Pressure Midget Chlor-O-Feeder
0-6 gal./hr. 30-200 lbs./sq. in.



Triplex Chem-O-Feeder
0-24 gal./hr. 0-100 lbs./sq. in.



High Pressure Automatic and Proportional Chem-O-Feeder
0-5 gal./hr. 30-200 lbs./sq. in.

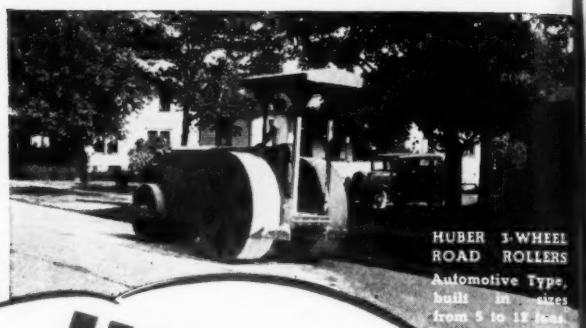


Low Pressure Automatic and Proportional Chem-O-Feeder
0-5 gal./hr. 4-100 lbs./sq. in.

BRING US YOUR WATER TREATING AND PROPORTIONING PROBLEMS

% PROPORTIONEERS, INC. %

96 CODDING STREET, PROVIDENCE 1, R. I.



HUBER 3-WHEEL ROAD ROLLERS
Automotive Type, built in sizes from 5 to 12 tons.

HUBER taught us a few things about ROAD MACHINERY

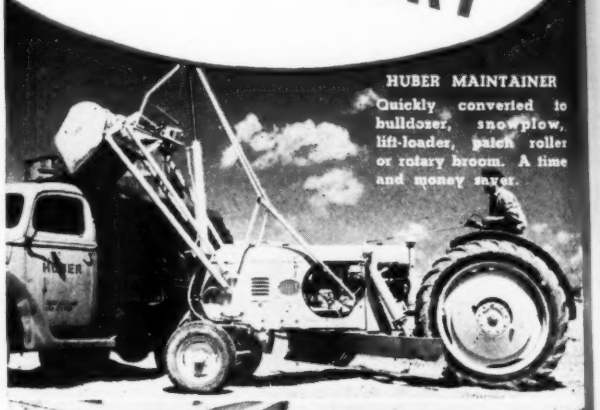
The moment you put Huber Road Machinery to work, you will discover three things, like many road men have done.

FIRST – you will find that Huber's practical design – the result of 35 years experience in close contact with road men, readily measures up to the job it has to do.

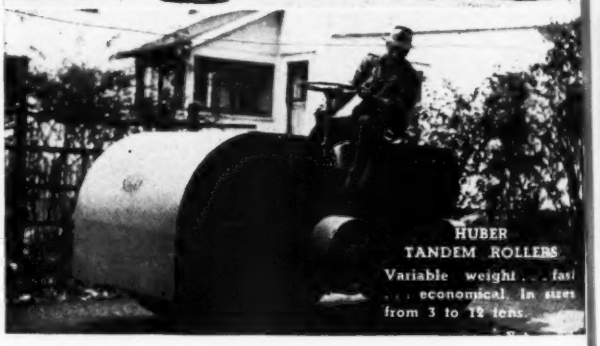
SECOND – you will find that Huber Road Machinery has all of the necessary features incorporated into it that make for speedy performance ... plenty of power and stamina ... versatility ... and maximum maneuverability to work in tight places.

THIRD – you will find, as hundreds of users have, that Huber Road Machinery saves you money. Its capacity to stay on the job ... its low operating costs ... its trouble-free service are factors not to be overlooked.

Your nearest Huber distributor will be glad to give you more details. Drop in and see him right away.



HUBER MAINTAINER
Quickly converted to bulldozer, snowplow, lift-loader, patch roller or rotary broom. A time and money saver.



HUBER TANDEM ROLLERS
Variable weight ... fast ... economical. In sizes from 3 to 12 tons.

THE HUBER MFG. COMPANY • MARION, OHIO, U. S. A.

HUBER

3 Wheel • Tandem

ROAD ROLLERS *and* MAINTAINERS

When Trouble-Free, Low-Maintenance, Clog-Proof Pumping of Sewage is Needed, Flush-Kleens are Specified

Because-

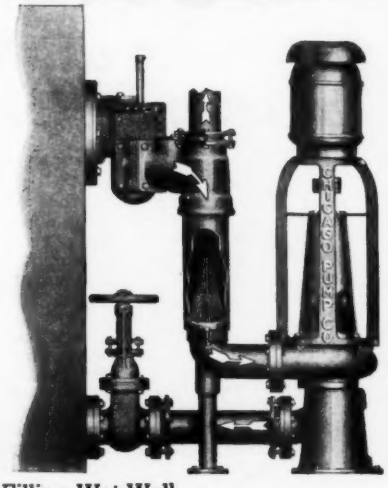
They Cannot Clog as Solids Do Not Pass the Impeller

"Flush-Kleen" pumps provide automatic, trouble-free service in sewage lift-stations. They require no manual attention except periodic lubrication and inspection and no labor is required for disassembling and cleaning clogged pumps as with other types.

Another factor which greatly reduces maintenance requirements is that "Flush-Kleens" have less of a wear factor than other pumps. This is due to the fact that the impellers handle only strained sewage. No solids pass through the impeller to cause excessive strain and wear on impeller, shaft, bearings or motor; pumps remain in balance and operate economically with little attention.

Duplex "Flush-Kleen" Sewage lift Station at Braintree, Mass. Each pump discharges 400 G.P.M. against 65 ft. head.

"Flush-Kleens" operate alternately



Filling Wet Well

- Sewage flows through inlet pipe.
- Coarse matter is retained on strainer.
- Strained sewage flows through idle pump to wet well.

Pumping

- Strained sewage is pumped from wet well.
- Coarse matter is backwashed from strainer.
- Special check valve closes; sewage and coarse matter are pumped to sewers.

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION.

2348 WOLFRAM STREET — **CHICAGO 18, ILLINOIS**

Flush-Kleen, Scru-Peller, Plunger, Horizontal and Vertical Non-Clogs, Water Seal Pumping Units, Samplers.

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

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APRIL, 1948

Cut TRACTOR COSTS 1/2

with an Ottawa

HYDRAULIC FRONT-END

LOADER

Get Twice as Much Out of The Tractors You Now Own

Ottawa Industrial Hydraulic Front End Loaders are available for light as well as heavy model industrial tractors. Every Ottawa Loader has been designed for maximum efficiency on the tractor with which it is used. Ottawa engineers have worked closely with leading tractor manufacturers in developing loaders for specific tractors—Loaders that meet these manufacturers' specifications for capacity efficiency and sturdiness.

Ottawa Industrial Loaders and their attachments are enabling State and County Highway Departments as well as other Industrial tractor owners to cut operation costs over ½ on both light and heavy tractors.
Keep your tractors working all year 'round. Put them to work on these jobs when they would normally be idle.

1. **Load trucks with cinders, sand or salt for treatment of icy streets or highways.**
2. **Clear sidewalks of snow using right or left angle snow blade attachment.**
3. **Snow removal from business district streets by using light bulldozer.**
4. **Backfilling and leveling of roadway shoulders with light dozer blade.**

Consult your industrial tractor dealer. If he can't supply you have him write or write direct for full information and price list.

Ottawa STEEL PRODUCTS, Inc.
INDUSTRIAL DIVISION
OTTAWA, KANSAS • U. S. A.

PUBLIC WORKS Magazine

Founded in 1896

Devoted to the interests of the engineers and technical officials of cities, counties and states

Vol. 79, No. 4

W. A. HARDENBERGH and A. PRESCOTT FOLWELL
Editors

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Published monthly by PUBLIC WORKS JOURNAL CORPORATION
Editorial and advertising offices: 310 East 45th St., New York 17, N. Y.

W. A. HARDENBERGH, *President;* CROXTON MORRIS, *Vice President and Treasurer;* A. PRESCOTT FOLWELL, *Secretary. Advertising representatives:* New York: ARTHUR K. AKERS, *Advertising Manager;* Chicago 11: LEWIS C. MORRIS, *Western Manager,* 612 No. Michigan Ave.; Cleveland 10: ROBERT J. SHEA, 2 Villa Beach, 15445 Lake Shore Blvd.; Los Angeles: SIMPSON-REILLY, LTD., Garfield Bldg.; San Francisco: SIMPSON-REILLY, LTD., Russ Bldg.; Seattle 4: SIMPSON-REILLY, LTD., New World Life Bldg. SUBSCRIPTION RATES: U.S.A. and Possessions, $3. All other countries, $4. Single copies, 35¢ each.

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100% Self-Contained Gasoline Hammer
PAVING BREAKERS
Busting—Cutting
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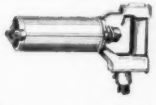
ELECTRIC HAMMERS
4 Sizes—⅜" to 2" Cap.



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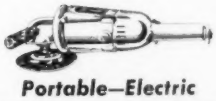
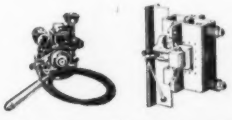
ELECTRIC DRILLS
3/16" to 1" Cap.



Portable—Electric
GRINDERS—SANDERS



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Drilling, cutting and chipping in concrete and masonry—drilling, sanding, buffing and polishing metal and wood—grinding welds and wire brush work—vibrating concrete—

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Write for Literature

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660 Lexington, Homer City, Pa.

200,000-GALLON ELEVATED TANK

. . . furnishes FULTON with Gravity Water Pressure

Gravity water pressure, provided by an elevated tank, is *hard to beat* when it comes to smoothing out pressure variations in a water distribution system. The 200,000-gal. Horton tank shown at the left was installed to provide gravity water pressure for the 10,000 residents of Fulton, Mo. The advantages of gravity pressure do not stop with an improvement of pressure in the system. Other advantages are lower pumping costs, more dependable supply of water for fire protection, maintenance of pressure during temporary power failure and lower insurance rates for the city.

Horton elevated steel tanks are built in capacities up to 2,000,000 gals. for municipal service. Why not write our nearest office for quotations on Horton elevated tanks when providing a *dependable* gravity water supply for your city.

ENGINEERING DATA

Source of Water—wells
Area Served—5 square miles
Storage Capacity—
200,000 gals. in elevated storage
300,000 gals. in reservoirs
Length of Distribution Mains—19.22 miles
Number of Customers—approximately 1,500

HORTON

STEEL STORAGE TANKS
. . . for municipal service

CHICAGO BRIDGE & IRON COMPANY

Plants in Birmingham, Chicago, Salt Lake City, and Greenville, Pa.

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Atlanta 3 . . . . . 2123 Healey Bldg.
Havana . . . . . 402 Abreu Bldg.

When writing, we will appreciate your mentioning **PUBLIC WORKS**

The Editor's Page

Using Engineers Effectively

The most effective use of engineers, if a national emergency should arise, is a matter of the utmost importance to our future. The National Resources Security Board is now taking steps to determine the best methods for cataloging the technical skills of the nation and for utilizing them most effectively in case of an emergency.

A basic difficulty in doing this is the present gap that exists in understanding and in thinking between the civilian profession and the engineering arms of the Army and the Air Force. Much of this stems from recent legislation which, in effect, removed the taint of professionalism from the Corps of Engineers of the future by throwing open the corps to men without engineering training or experience. As a consequence, common ground is lacking on which military and civilian engineers can meet understandingly.

For the most effective use of civilian engineers in an emergency, as well as for the fullest peace-time cooperation between the civilian profession and the military engineers, there must exist a confidence that cannot be attained under present conditions. Army and Air Force engineers must be members in full standing of their profession; they must be in full touch and understanding with civilian engineering progress and devlopments; and they must be able to apply to military problems the knowledge and the views of the civilian profession. When these objectives are accomplished, and not until then, full and effective cooperation will be possible, and civilian engineers will not hesitate to work with the military for they will know that their abilities and their training will be utilized wisely.

Getting Rid of Rats

As one phase of the food conservation program being conducted by the Government, a nationwide campaign against rats is being initiated. A lot of sound material on rat control and rat proofing has been sent us by the Division of Information, Department of Agriculture, Washington, D. C. We believe that this will be made available, on request, to any municipal, county or state agency, if they do not already have it.

There is no question regarding the undesirability of rats nor the damage that they can do. But they cannot be controlled by any one brief campaign; a continuing, well-planned effort is necessary, with continuous good municipal housekeeping as the first essential. Inadequate or careless refuse collection and disposal is often a big factor in rat prevalence. We like these new, large metal containers for hotels, restaurants and similar large refuse producers. They are durable and rat-proof. For smaller places a tight metal container is needed. Adequate refuse collection equipment, with tight, covered bodies is the next step in providing against rodent prevalence; and good containers and good collection equipment must be followed up by proper final disposal. The old open or lightly covered dump will produce enough rats to keep any community well infested. That should be the first thing to go in any campaign to get rid of rats.

Population Changes and Municipal and County Services

Smaller families are probably in prospect, and this means more houses for a given population. Thus, population forecasts based on present conditions may not provide a safe guide for the future. More houses means a greater area for the same population, and this, in turn means more paving, more water mains, more sewers, more police coverage and more fire protection services.

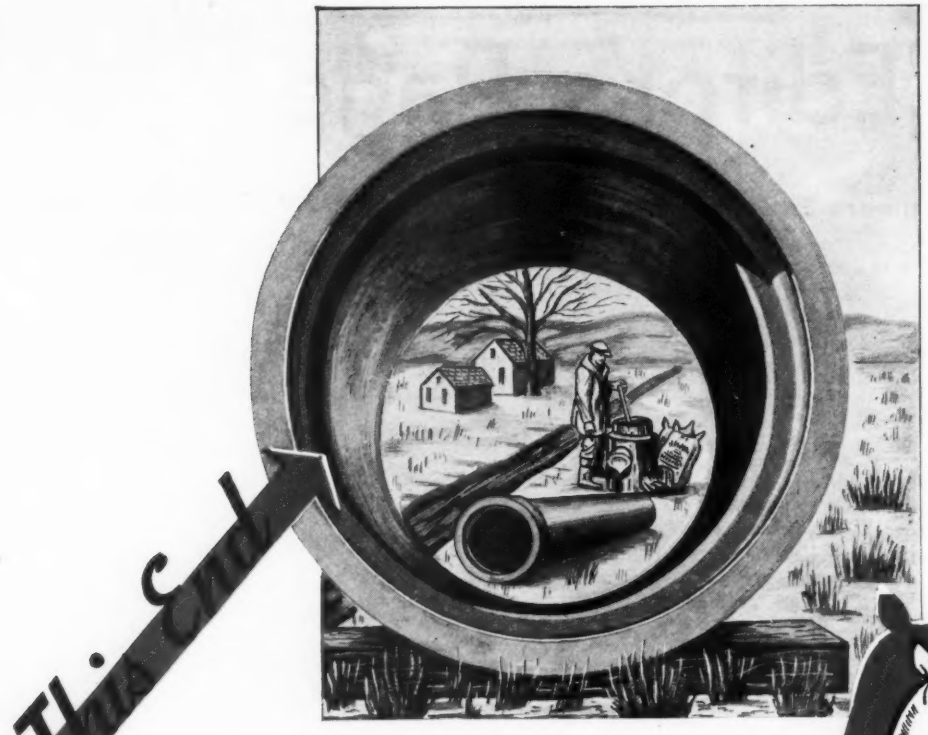
There may be even broader implications, in that in bursting beyond the bonds of our present-day municipalities, these new communities will require sewer systems and treatment plants, water supply, and refuse disposal. Annexation to existing municipalities may not be the answer. Decentralization may result in lower tax income to the central municipality; and annexation may tend toward higher, but compensating, taxes for the annexed areas.

Not only municipal and county governments—if our counties have any government—but also state health departments, and other agencies responsible for the welfare of the people, must consider these problems, do a bit of research on where they may trend, and try to develop an answer.

Mechanical Removal of Sludge From Drying Beds

One of the jobs in which failure to substitute machinery for hand labor has been most striking is that of removing sludge from drying beds. Of course, the best way to avoid this is to use sludge dewatering filters and a belt conveyor. But those who now have sand beds may wish, or be obliged, to continue their use. In almost every plant, removal of the dried sludge is done by hand; but if there are any plants using mechanical equipment for this purpose, we would be glad to hear about them. In general, we may expect about 1¼ cubic yards of dry sludge per million gallons of sewage. With present day labor costs, and if labor is available, the cost of removal is probably in excess of $1 per yard.

There is plenty of equipment suited to picking up material and loading it into trucks, but operation of such equipment on the usual type of sand bed offers many problems. Use of stronger under-drainage materials might help by providing a support sufficient to carry a front-end loader or a light bulldozer followed by a bucket loader. Other potentially useful devices might include a drag bucket operating between two small towers; or a movable belt conveyor. Anyway, we'll be glad to hear how our readers have solved their problems in this line.



DOWN through the years the development of cast iron bell and spigot pipe has resulted in a product that can unquestionably last for a century and more. The jointing compound used should naturally be a matter of deep concern. HYDROTITE, time tested and proven for over 30 years, is the one jointing compound you know you can rely on. Self-calking, self-sealing HYDROTITE costs less to buy and use, requires minimum of unskilled labor, makes tighter joints and withstands the effects of vibration and time. Used with FIBREX, a bacteria free, easy to use packing, it makes an unbeatable water tight joint.

Always use FIBREX, the sanitary, bacteria-free packing that costs about 30% less than braided jute. Sample on request.

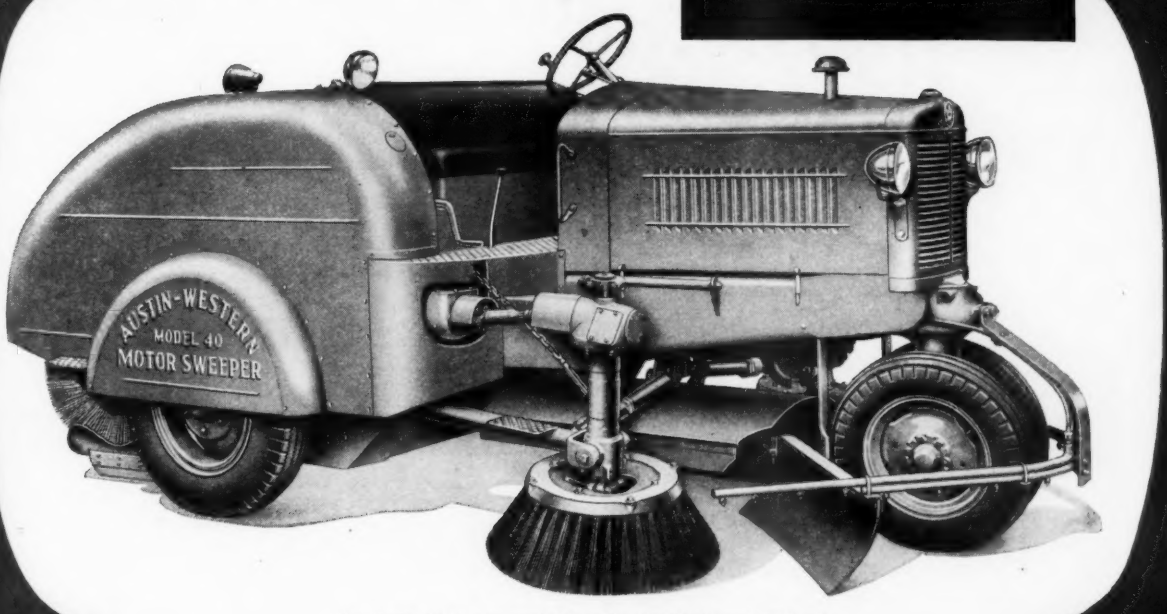
HYDRAULIC DEVELOPMENT CORP.

50 CHURCH STREET • NEW YORK, N. Y.

***Plant at* WEST MEDFORD, BOSTON, MASS.**

Get Superlative Performance with

The Model 40 MOTOR SWEEPER



The Model 40 is also available with windshield and steel cab.

These 11 features *(many of them exclusive)* are responsible for its ability to OUTPERFORM

- 2-yard Hopper, with flushing device and hydraulic control.
- 36-inch, bump-proof, oscillating gutter broom, with tilt and pressure adjustments.
- NO CONVEYOR — the 5-foot, gear-driven, rear broom sweeps directly into the hopper.
- 7-foot sweeping width with one gutter broom (right-hand or left-hand).
- 9-foot sweeping width with 2 gutter brooms, for one-way streets and large areas.
- Load can be transported any desired distance.
- 3-wheeled design, with full maneuverability and front-mounted motor.
- Handles like a truck, for simplicity, visibility and public safety.
- Steep grades are no problem, with positive drive to both rear wheels.
- Dumps to the rear and resumes sweeping in less than a minute, without backing or leaving path of travel.
- Leaf Broom attachment provides fast, efficient removal of leaves.

AUSTIN-WESTERN COMPANY, AURORA, ILLINOIS

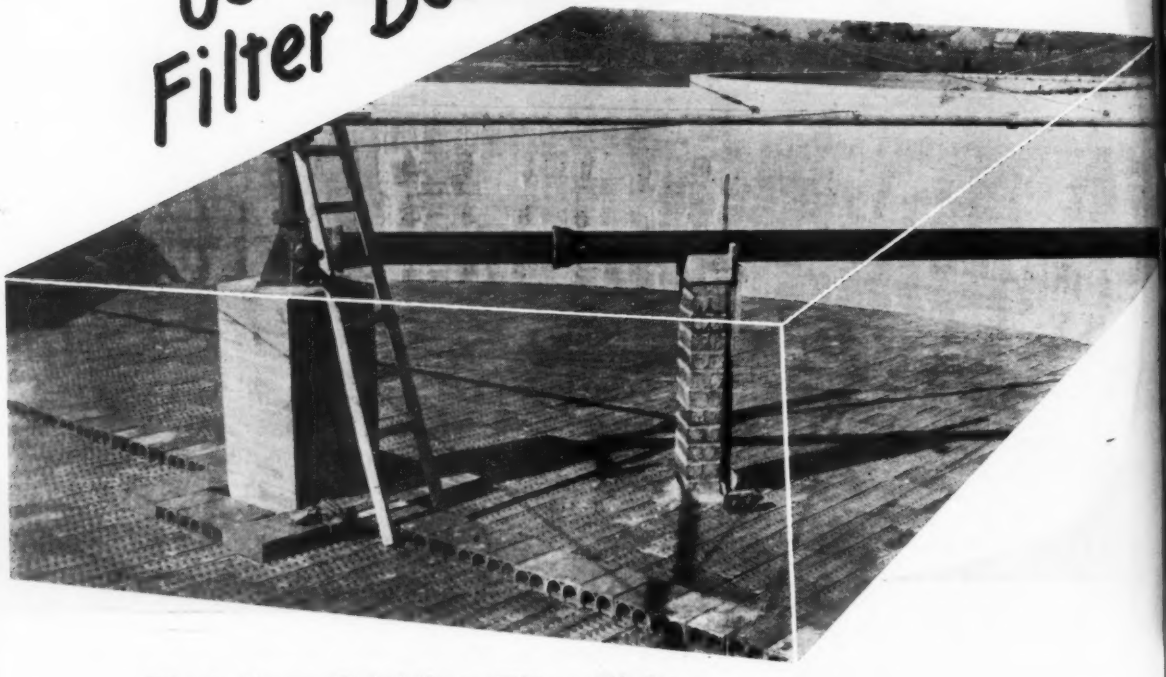
BUILDERS OF ROAD MACHINERY

Austin Western

SINCE 1859

For Better Results From Trickling Filters

Use Vitrified Clay Filter Bottom Blocks



Start Your Trickling Filter Right

You will save a lot of worry if you build your trickling filter "right" from the bottom up. An underdrainage system that allows plenty of air to circulate uniformly through the filter medium while the sewage is flowing down is a prime necessity for good operation. As the same time it should be highly resistant to acids and chemicals, non-clogging and give lifetime service without replacement.

Vitrified Clay Filter Bottom Blocks made by the members of the Trickling Filter Floor Institute meet all those specifications. They are specially designed to provide the best possible floor for trickling filters. They are laid quickly and easily by unskilled labor. Hundreds of installations in the past 20 years prove their long, trouble-free service. For latest engineering data, prices, etc., write any of the following members of the Trickling Filter Floor Institute. A new Trickling Filter Handbook has just been published.

- *Check these advantages:*
- WON'T CLOG
- LIGHT WEIGHT
- RESIST ACIDS
- LONG LIFE

Easy to Lay

AYER-McCAREL-REAGAN CLAY CO.
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METROPOLITAN PAVING BRICK CO.
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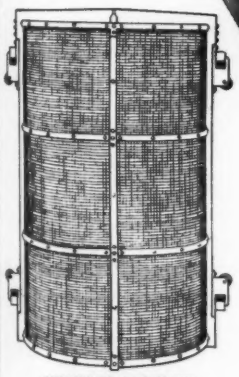
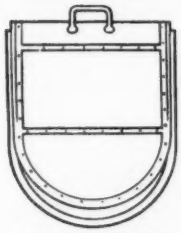
For Strength and Light Weight in Built-up Equipment

Everdur Metal

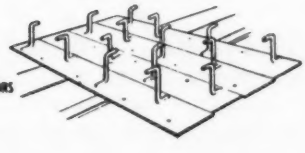
WELDED SLIDE GATES



SCREEN WIRE AND FRAMES



ADJUSTABLE OUTLET WEIR



BEARING PLATES WITH WELDED ANCHORS

EVERDUR* Copper-Silicon Alloys are produced in compositions suitable for rolling, drawing, spinning, forging and hot or cold working. Alloys are available that are suited to welded assembly of built-up equipment that is strong and durable, yet light in weight and easy to operate.

Because Everdur Metal combines high strength with the corrosion resistance of copper, it is especially well adapted to the construction of any equipment which requires an extra measure of protection against corrosion.

Proof of the economical long life provided by Everdur may be found in many waterworks and sewage plants throughout the country . . . where 20-year-old installations are still in service. The American Brass Company does not manufacture equipment, but supplies Everdur Alloys in commercial forms to leading fabricators. Write for Publications E-11 and E-5. 46215 Rev.

* Reg. U. S. Pat. Off.

ANACONDA

Everdur

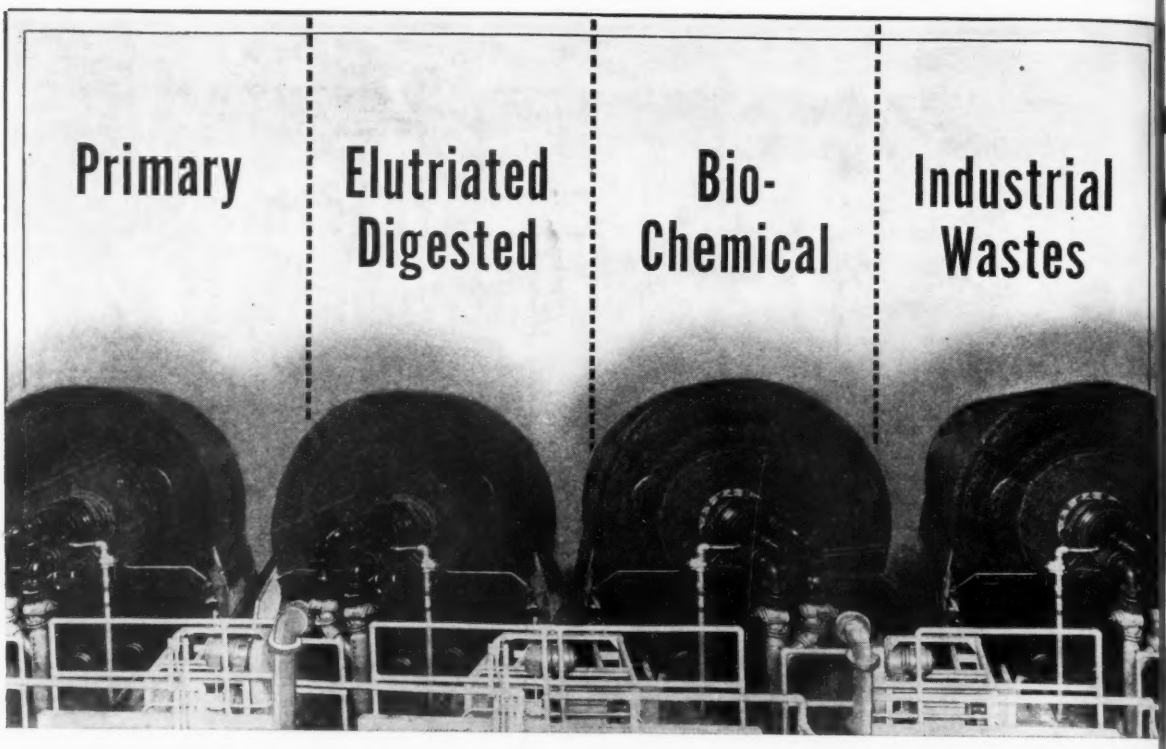
COPPER-SILICON ALLOYS

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ont.*



OVER 1000 TONS OF DRY SOLIDS ARE DEWATERED DAILY

The ability of Conkey Sludge Filters to effectively dewater various types of sludges and wastes—in large or small communities—has been proved for many years.

Municipal and consulting engineers should let General American engineers work with them when planning extensions to present dewatering facilities or constructing new plants. They will benefit from the experience of engineers who have a correct understanding of the vital factors which assure an efficient and economical installation, such as, feed consistency, conditioning of chemicals, conditioning time, application and mixing, as well as the all important knowledge of filter construction.

Other
GENERAL AMERICAN EQUIPMENT
SLUDGE DRYERS
SLUDGE GAS HOLDERS
STEEL STACKS
TURBO-MIXERS
STORAGE TANKS
THICKENERS
SCREENING DEWATERERS

Write for Bulletin No. 100 which gives further information on Conkey Sludge Filters.

General American
TRANSPORTATION CORPORATION
process equipment • steel and alloy plate fabrication
SALES OFFICE: 10 East 49th St., Dept. 830 New York 17, N. Y.
WORKS: Sharon, Pa., East Chicago, Ind.
OFFICES: Chicago, Sharon, Louisville, Orlando, Washington, D. C. Pittsburgh, St. Louis, Salt Lake City, Cleveland.

PROCESS EQUIPMENT DIVISION GENERAL AMERICAN TRADE MARK

Announcing

INCREASED POWER

TD-14

An increased-horsepower engine now powers the TD-14 Diesel crawler, stepping up its work capacity through increased drawbar horsepower. At 1400 r.p.m. governed engine speed, this heavy-duty, well-balanced, 4-cylinder International Diesel delivers . . . . .

57 Drawbar Horsepower

For complete information, write for our new folder: Form No. A-92-LL.

INCREASED POWER

TD-18

Marked increase in its engine horsepower gives the International TD-18 new power at the drawbar, greater work capacity and new performance characteristics. At 1300 r.p.m. engine speed, this popular 6-cylinder International Diesel delivers

80½ Drawbar Horsepower

Get all the facts. Write for our new folder: Form No. A-93-LL.

INTERNATIONAL HARVESTER

Industrial Power Division • INTERNATIONAL HARVESTER COMPANY • 180 North Michigan Avenue, Chicago 1, Illinois

INTERNATIONAL *Industrial* **POWER**

CRAWLER TRACTORS • WHEEL TRACTORS DIESEL ENGINES • POWER UNITS

When writing, we will appreciate your mentioning PUBLIC WORKS

Look to the LEADER

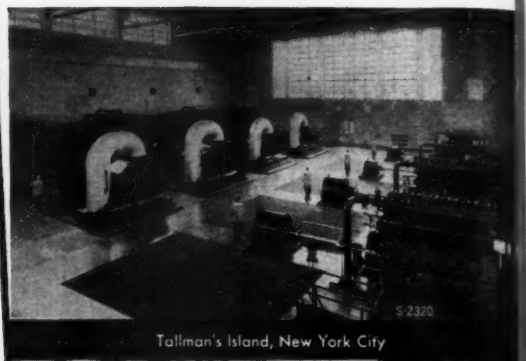
FOR LOW-COST POWER

As your municipality prepares to complete war-delayed plans for modernizing sewage treatment, consider the advantages Worthington offers you.

In providing 60 heavy-duty gas engines totaling over 17,000 hp to 30 communities between 1934 and 1941, Worthington kept in step with all the developments in modern sewage treatment plants. While its 500 hp installed in 1934 was growing to 7200 hp installed in 1941, Worthington not only advanced in design leadership but also built up invaluable experience in fitting the right engine to specific conditions.

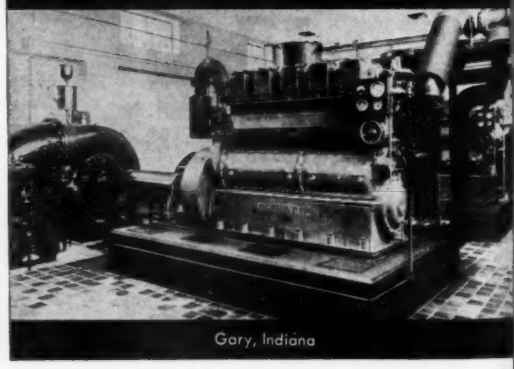
Now, at the beginning of the "new era" in sewage treatment development, Worthington offers a complete line of both spark ignition gas engines and dual fuel Diesel engines in sizes ranging from 225 hp to 1645 hp in single units.

That Worthington leads today, as in the past, is evidenced by a recent contract to supply the City of Boston with 5 engines totaling approximately 3000 hp, in both types of engines. For further proof that *there's more worth in Worthington*, write for literature. *Worthington Pump and Machinery Corporation, Engine Division, Buffalo, New York.*


Tallman's Island, New York City

Sioux Falls, South Dakota

Greensboro, North Carolina


Gary, Indiana

WORTHINGTON

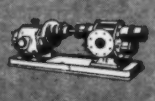
E7-7

YOUR PARTNER IN POWER PROGRESS

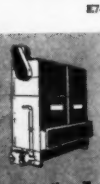
Diesel engines, 150 to 3,520 hp . . . gas engines, 175 to 3,290 hp . . . dual fuel Diesel engines, 225 to 3,290 hp.

WORTHINGTON-BUILT AUXILIARIES

Air King Compressors


Oil Transfer Pumps

Cooling Water Circulating Pumps

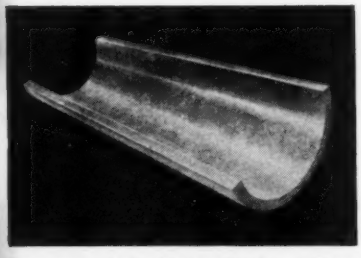

Evaporative Type Engine Water Cooler

Engineering Facts about

Johns-Manville TRANSITE PRESSURE PIPE

Carrying Capacity

EXAMINATION of the interior wall of Transite* Pressure Pipe will quickly disclose its uniformly smooth surface. This smoothness, imparted during manufacture by forming each length under pressure on a highly polished steel mandrel, accounts for the high flow coefficient of Transite Pressure Pipe—C-140, based on the Williams and Hazen formula.



The unretouched photograph above shows Transite's exceptionally smooth interior surface—imparted by the polished steel mandrel on which the pipe is made.

Moreover, because Transite is made of asbestos and cement, it is inherently and completely immune to tuberculation. This means that the initial high carrying capacity of this pipe remains high in service—a fact which has been confirmed by accurate Pitometer tests.

One important advantage of Transite's maintained high carrying capacity is the assurance of an ample flow of water for both normal and fire-fighting needs in the years to come. Pumping equipment can be operated closer to peak efficiency; pumping costs can be held to a minimum. Taxpayers can receive the benefits of the favorable fire insurance rates which result from a modern, efficient water distribution system of ample capacity.

Accurate Pitometer tests conducted in the field verify Transite's maintained carrying capacity of C-140.

Another advantage—the engineer may design his water system with pipe of minimum diameter, rather than resort to larger pipe than would otherwise be necessary in order to offset the progressive reduction in flow caused by tuberculation. This practice is not necessary when Transite Pressure Pipe is specified.

As indicated by tests, Transite's *maintained* carrying capacity helps provide the abundant fire-flow essential to adequate protection and to favorable fire insurance rates.

And, of course, since tuberculation is not a problem, the costly expense otherwise involved in cleaning and lining of water mains can be eliminated.

A maintained high-carrying capacity is one of many advantages of Transite—the modern asbestos-cement pipe that was engineered to carry water more efficiently and more economically. For further facts, write for Brochure TR-11A. Address Johns-Manville, Box 290, New York 16, New York.

*Transite is a registered Johns-Manville Trade Mark

JOHNS-MANVILLE JM PRODUCTS

THERE MUST BE A REASON NEARLY

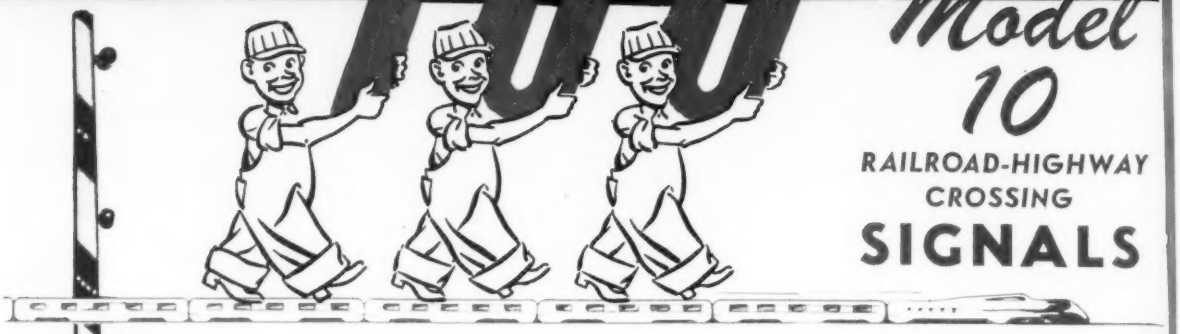
100

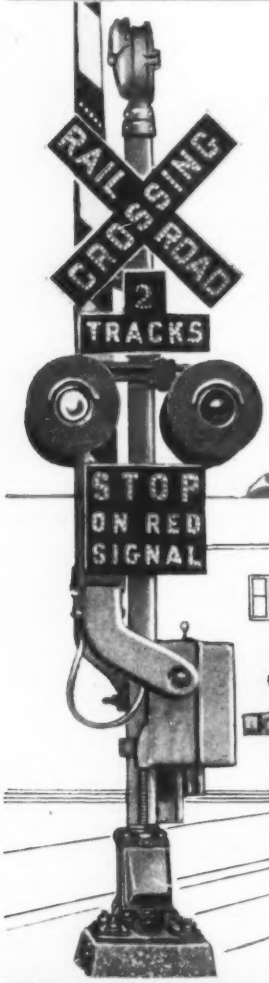
RAILROADS HAVE INSTALLED

Model 10

RAILROAD-HIGHWAY CROSSING

SIGNALS





Model 10 Signals are the most thoroughly dependable grade crossing protection it is possible to buy. During their eleven years of service, Model 10's have proved their efficiency, establishing perfect performance records at thousands of railroad-highway crossings throughout the world. Since the first Model 10's were installed in June, 1936, **NOT ONE FATALITY** has ever occurred as the result of operation failure on the part of Model 10's. In recognition of their contribution to public safety, Model 10 Signals have been awarded the Certificate of Merit by the New York Museum of Science and Industry.

Model 10 Signals

- **Operate automatically — as dependably as semaphore signals.**
- **Safeguard against "second train" accidents.**
- **Permit the fast flow of rail and highway traffic.**

Write for Bulletin G18—PW4

U. S. Pat. Nos. 2,137,196; 2,362,710; 2,372,579. Pat'd in Canada 6-27-39

MODEL 10 HIGHWAY CROSSING SIGNALS ARE THE PRODUCT OF

WESTERN RAILROAD SUPPLY CO.

Designer and Manufacturer of Safety Devices for Railroads

Foreign Representatives:
GUITERMAN COMPANY, INC., 35 SOUTH WILLIAM ST., NEW YORK 4, N. Y., and LONDON
INTERNATIONAL STANDARD ELECTRIC CORP., 67 BROAD ST.,

2406-2436 SOUTH ASHLAND AVE.
CHICAGO 8, ILL.

CERTIFICATE OF MERIT for Safety AWARDED TO WESTERN RAILROAD SUPPLY CO. BY THE NEW YORK MUSEUM OF SCIENCE AND INDUSTRY

how do you pick a pump?

When it comes to pumps...

on dependability?

Year after year, Fairbanks-Morse Vertical Turbine Pumps deliver outstanding performance. Fool-proof operation requiring no priming . . . automatic solenoid oiler . . . precision construction for smoother flow . . . and backed by the Fairbanks-Morse reputation for quality, they assure dependability *plus!*

on adaptability?

Whatever the job requirements . . . deepwell or close-coupled, electric power, gasoline or Diesel engine, or belt drive . . . Fairbanks-Morse Vertical Turbine Pumps are readily adaptable for all service conditions.

on compactness?

A Fairbanks-Morse Vertical Turbine Pump is compactness itself . . . permits considerable savings in floor space as compared to ordinary pumps of comparable capacity. It requires no complicated piping hook-ups. Installation is easy and economical.

on service?

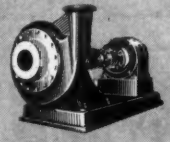
The Fairbanks-Morse Pump Dealer organization is founded on service. They *know* pumps . . . can offer you unmatched service and assistance. Backed by the Fairbanks-Morse production and engineering resources, they can help you pick the pump that will give you most for your pumping dollar. Fairbanks, Morse & Co., Chicago 5, Illinois.

FAIRBANKS-MORSE

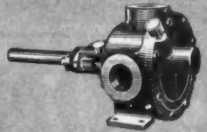
A name worth remembering

DIESEL LOCOMOTIVES • DIESEL ENGINES • PUMPS • SCALES • MOTORS • GENERATORS
STOKERS • RAILROAD MOTOR CARS and STANDPIPES • FARM EQUIPMENT • MAGNETOS

A FEW OF THE COMPLETE LINE OF FAIRBANKS-MORSE PUMPS


Trash Pump

Side-Suction


Rotary

Builtogether

When writing, we will appreciate your mentioning PUBLIC WORKS

THE PIPE USERS ANSWER THEIR OWN $64 QUESTION!

Based on actual survival and retirement experience, what do we really know about the useful life of water works facilities? That was the $64 question water works men asked themselves. Here is how they came up with the answer.

A committee was formed by 3 water works organizations to direct a survey of the recorded experience of 25 cities, large and small, from Canada to Florida. These cities were selected as comprising a cross-section of various water service conditions. The facts were obtained by and from water works men. The survey has been completed and the findings published by the American Water Works Association.

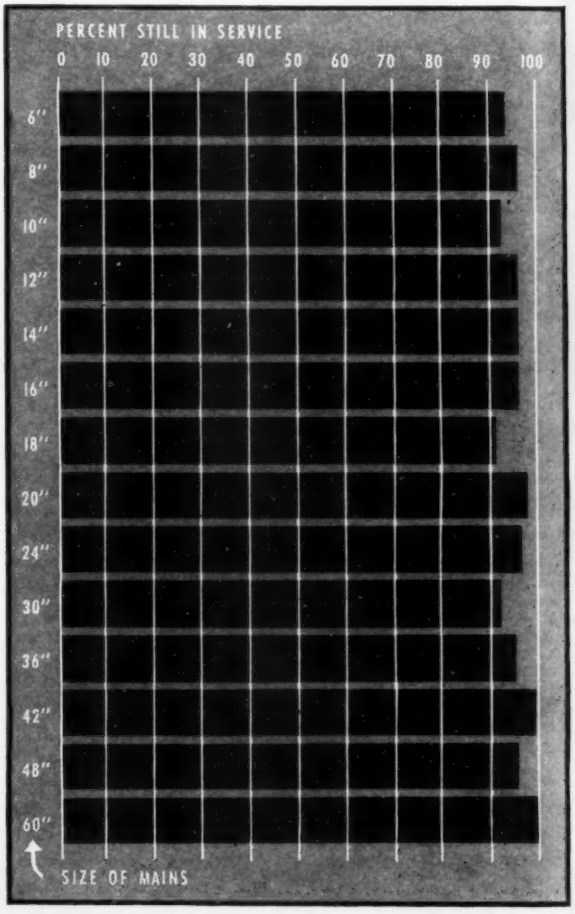
In the 25 cities surveyed, 50 million feet of cast iron water mains, sizes 6-inch and over, had been laid in the 128 years since 1817. The survey revealed, as the chart opposite shows, that 96% of all cast iron water mains ever laid in these 25 cities, sizes 6-inch and over, *are still in service!* An official record that speaks for itself.

The cast iron pressure pipe industry, in spite of raw material shortages, achieved in 1947 one of the biggest production years in footage in the history of the industry, and has recently installed additional footage capacity. Cast Iron Pipe Research Association, Thomas F. Wolfe, Engineer, 122 South Michigan Avenue, Chicago 3, Ill.

96% of all cast iron water mains* laid in these 25 cities over a period of 128 years is still in service.

Alexandria, Virginia
Babylon, New York
Clinton, Iowa
Clyde, New York
Denver, Colorado
Des Moines, Iowa
Detroit, Michigan
Huntington, West Virginia
Jamaica, New York
Merrick, New York
Norwich, New York
Ottawa, Ontario
Philadelphia, Pennsylvania
Portland, Maine
Rochester (Suburban), N. Y.
St. Mary's, Pennsylvania
St. Paul, Minnesota
Sag Harbor, New York
Scranton, Pennsylvania
Springfield, Massachusetts
Summit, New Jersey
Syracuse (Suburban), N. Y.
Utica, New York
West Palm Beach, Florida
Winnipeg, Manitoba

*Sizes from 6 to 60 inches.



CAST IRON PIPE SERVES FOR CENTURIES

Save...

Time, Money and Labor in making pipe joints

« « « The only field equipment necessary to make a Universal Cast Iron Pipe Bolted Joint is a Ratchet Wrench.

by using

UNIVERSAL*
CAST IRON PIPE

(PIPE and JOINT are ONE)

*Reg. U.S. Pat. Off.

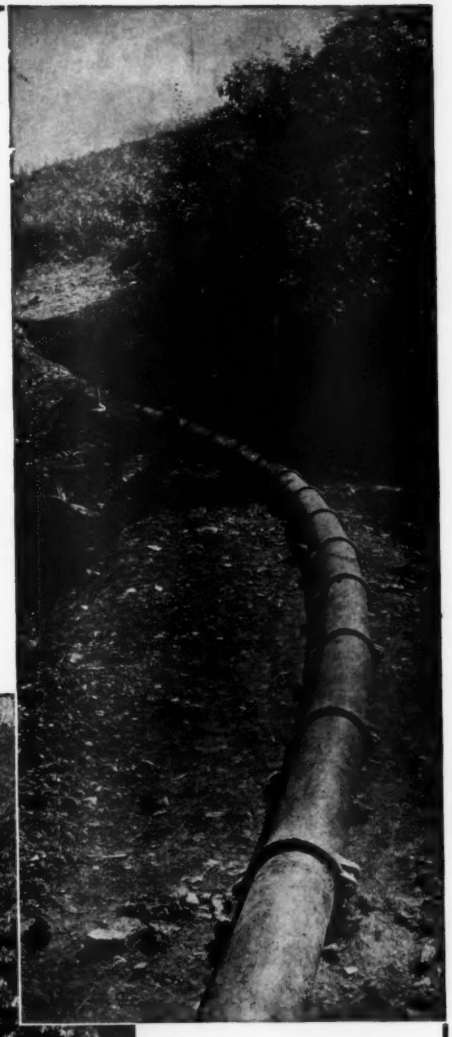
Outstanding Advantages:

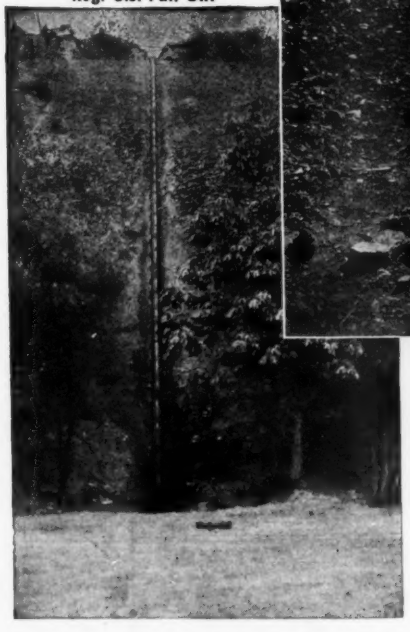
1. *No calking or pouring of lead or lead substitutes. No gaskets used.*
2. No bell holes to dig. Can be laid in a narrow trench. Cost of wide trenching is eliminated.
3. *Can be laid with SPEED. Easier and cheaper to install because only two bolts need to be inserted in the lugs, tightened with a ratchet wrench (the only tool needed), and the completed joint is made in a few minutes. Experienced workmen are not needed.*
4. Nothing to deteriorate; nothing to work loose; no leakage; no maintenance cost.
5. Flexibility: Universal pipe is very flexible. It withstands expansion, contraction, unequal settlement, vibration and shock, and electrolysis. Many curves are laid with straight lengths and do not need special fittings.
6. *Universal pipe can be laid on rocky soil, under water and in sub-zero weather.*

Specify *UNIVERSAL PIPE* for water mains and sewers

Furnished in hot tar dipped, cement lined, and enameline lining.

THE CENTRAL FOUNDRY CO.
386 FOURTH AVENUE, NEW YORK 16





Above *All straight lengths of Universal pipe in this curve.*

At left *16" pipe laid on a 45-degree slope. Note deflection at top to level ground without fittings.*

↓ USE THE COUPON ↓

DEPT. C

THE CENTRAL FOUNDRY COMPANY
386 Fourth Avenue, New York 16

I am interested in SAVING LABOR, TIME, MONEY and EQUIPMENT in pipe-laying. Send me the UNIVERSAL catalog.

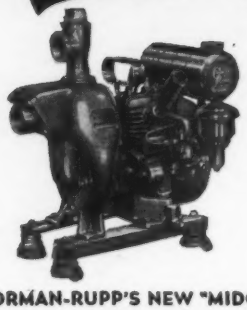
Name .....

Position .....

Address .....

.....

COMPARE O. S. C. SEPTIC TANK CLEANING



WITH OLD FASHIONED, UNSANITARY METHOD

When a Sanitary Service Operator puts a new Gorman-Rupp Odorless Sanitary Cleaner on the job these are the results:—

1. A disagreeable job becomes pleasant, easy work.
2. Unsanitary methods and unhealthy conditions eliminated. Septic tank cleaning with an O. S. C. unit complies with or exceeds health regulations and requirements. It banishes open tanks, diaphragm hand pumps, shovels and other makeshift equipment.
3. It does each job more thoroughly, in a fraction of the time previously r quired. For example, 500 gal. tanks a cleaned in 15 minutes, 1000 gal. tanks 20 minutes.
4. It offers operators profit possibiliti far in excess of income with prese equipment and methods.
5. An O. S. C. unit has other profitab uses such as transporting water, eme gency fire fighting, sprinkling, d watering, etc.

Show this to Sanitary Service Ope ators in your community. For comple information write for Bulletin 7-ST-1

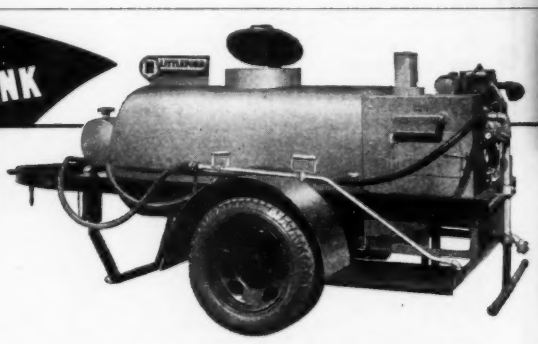
GORMAN-RUPP'S NEW "MIDGET" 1½" PUMP

FASTEST, self-priming, most efficient pump for general use. Weighs but 62 lbs. -- pumps 5500 GPH -- self-primes up to 30 ft. -- non-clogging, sturdy. Gorman-Rupp builds a complete line of pumps from the "HANDY", delivering 8 GPM, to large capacity pumps which deliver as high as 125,000 GPH.

THE GORMAN-RUPP COMPANY

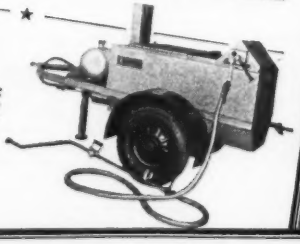
320 NO. BOWMAN ST., MANSFIELD, OHIO

3 USES for Littleford's No. 101 UTILITY SPRAY TANK



No. 155 Trail-O-Roller
Motorized, trails at any speed behind truck; converts hydraulically from roller to trailer or back again in two minutes. Compaction equal to five ton tandem.

84-HD Kettle
Repairs any road by applying asphalt to stones, gravel. Double heat circulation assures faster heating, faster draw-off of material, safest and most economical kettle operation.



Into this one unit Littleford has built three features essential to city, state, county and airport maintenance. (1) Spray Bar for small application work, (2) Hand Spray for repair and patch work, (3) Draw-Off Cock for pouring pot and crack filling work. Combine the No. 101 with Littleford's Trail-O-Roller and Tar Kettle and you have road maintenance units that give the utmost efficiency. Write today for full details.

MANUFACTURERS OF

"Tankar" Steam Heaters	"Spray Master" Pressure Distributors	Asphalt Supply Tanks
"Kwik-Melter" Roofers Kettles	Highway Brooms	No. 101 Utility Spray Tanks
Trail-O-Rollers	Tool Heaters	84-HD Asphalt Kettles
	Trail-O-Distributors	

BLACK TOP ROAD MAINTENANCE EQUIPMENT LB SINCE · 1900

LITTLEFORD

LITTLEFORD BROS., Inc.

452 E. PEARL ST., CINCINNATI 2, OHIO

A two-way stretch every forty feet

Here's a pipe line that can flex and stretch at every joint without losing its figure. Even earth movement near the riverbank, and the freeze-and-thaw of northern winters will leave it bottle-tight.

Each forty-foot section of strong, shatterproof steel pipe is cushioned against the stresses of underground service by the flexible Dresser Couplings which join it to its neighbors. The couplings, with their specially compounded rubber gaskets, harmlessly absorb expansion, contraction and other movement . . . assure continued joint tightness.

A Dresser-Coupled steel line makes for speedy installation, too. You use plain-end pipe in standard lengths. No need to waste time lining up ends exactly. Simply slip on the factory-made and tested couplings and tighten the bolts. Any workman who can use a wrench can do it. No guesswork, either. You get a permanently tight joint every time.

And with Dressers, you get the full advantage of modern, glass-smooth pipe linings. Dresser Couplings fit outside the pipe. There is no heat to damage lining—no need for workmen to go inside the pipe.

For top performance and an extra margin of safety, specify a Dresser-Coupled steel line. Detailed information on request.

PARTIAL LIST OF CITIES USING DRESSER-COUPLED STEEL LINES

Albuquerque, N. M.	Detroit, Mich.	New York, N. Y.
Boston, Mass.	Harrisburg, Pa.	Philadelphia, Pa.
Chicago, Ill.	Kansas City, Mo.	Saginaw, Mich.
Cleveland, Ohio	Milwaukee, Wisc.	Savannah, Ga.
Denver, Colo.	Newark, N. J.	Syracuse, N. Y.
	Washington, D. C.	

SIMPLE • FAST • FLEXIBLE • PERMANENT

Even in cramped quarters encountered in city work, Dresser Style 38 Couplings make permanently tight, flexible joints every time.

DRESSER COUPLINGS

ONE OF THE DRESSER INDUSTRIES

Dresser Mfg. Division, 59 Fisher Ave., Bradford, Penna. • In Texas: 1121 Rothwell St., Houston • In Canada: 60 Front St., W., Toronto
Sales Offices: New York, Chicago, Houston, San Francisco

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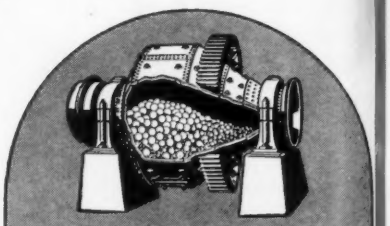
Sanitation Equipment by HARDINGE

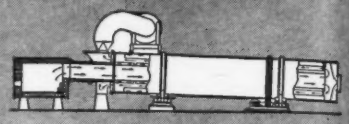
For the past forty-two years Hardinge engineers have been acquiring the "know-how" to manufacture and install process equipment for the sanitary engineering field.

Today, thousands of Hardinge installations in the United States, Canada, and South America — many of them engineered early in the century — provide ample evidence of the efficiency, low maintenance requirements, and long life of Hardinge products.

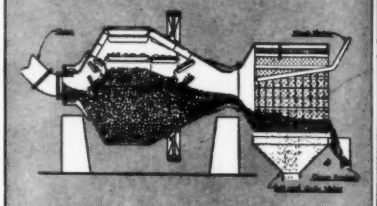
- **AUTOMATIC BACKWASH FILTER**
  A filter which cleans itself, automatically, without shut-down or change-over. Traveling backwash mechanism. Bulletin 46.
- **CIRCULAR CLARIFIERS**
  Double-spiral or cut-flight scrapers remove settled solids quickly. Discharge at tank center. Bulletin 35-C.
- **RECTANGULAR CLARIFIERS**
  Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. Bulletin 35-C.
- **FLOCCULATING EQUIPMENT**
  Slowly rotating paddles hold solids in suspension—create optimum conditions for flocculation. Bulletin 46.
- **RUGGLES-COLES DRYERS**
  Highly efficient rotary dryers in nine types. Model XH ideal for dehydration of garbage, sewage and sludge. Bulletin 16-C.
- **DIGESTERS**
  Sludge scrapers and scum breaker arms prevent scum accumulation, insure uniform gas production. Emit a dense digested sludge. Bulletin 35-C.
- **OTHER HARDINGE PRODUCTS**
  Hydro Classifiers, Counter-Current Classifiers, Agitators. Standard Sand Filters, Slurry Mixers, Diaphragm Pumps, Reversed-Current Air Classifiers, Grinding Mills of all types, Conical Scrubbers, Rotary Kilns-Coolers, Rotary Tubular Conveyors. Automatic Centrifugal Clutches, Constant-Weight Feeders, Disc Feeders, Drum Feeders.



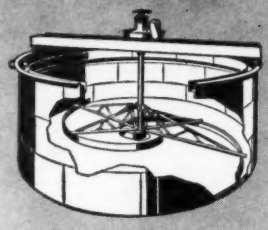
HARDINGE MILL



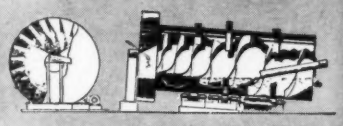
ROTARY DRYER



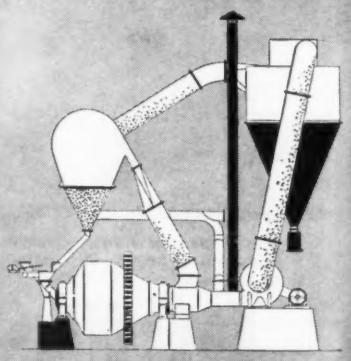
CONICAL SCRUBBER



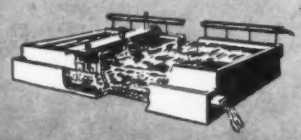
AUTO-RAISE THICKENER



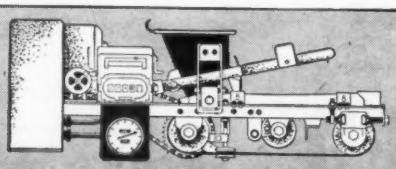
COUNTER-CURRENT CLASSIFIER



AIR CLASSIFIER



A.B.W. SAND FILTER



CONSTANT WEIGHT FEEDER

HARDINGE
COMPANY INCORPORATED

YORK, PENNSYLVANIA — 240 Arch St. • Main Office and Works
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When writing, we will appreciate your mentioning PUBLIC WORKS

VITRIFIED CLAY PIPE
HELPS SET NEW HOSPITAL STANDARDS

THE $770,000,000 hospital program being undertaken by the Corps of Engineers for the Veterans Administration is reaching new heights in hospital standards. These new standards are recognizable mainly in the vast array of facilities for both medical and psychiatric treatment . . . in the use of all of the known science and arts for returning a high percentage of the disabled to useful and self-respecting living.

These new standards are also reflected in modern designed-for-tomorrow buildings. Into these architectural masterpieces are going the world's finest construction materials.

Engineers on these projects recognize the vital importance of top-quality workmanship and materials *below* ground as well as above. That's why there is so much insistence on Vitrified Clay Pipe for sewerage and drainage lines. For Vitrified Clay Pipe is the only pipe impervious to the action of acids . . . chemicals . . . alkalies . . . rust . . . corrosion . . . disintegration.

This high resistance factor of Vitrified Clay Pipe gets a special vote of confidence from hospital designers. The pipe they specify *must* handle safely the acid and chemical wastes of hospital laboratories and facilities!

More than a mile and a half of Vitrified Clay Pipe is being used for the exterior sanitary and storm sewers of the 475-bed Veterans Administration Hospital being constructed at Wilkes-Barre, Pennsylvania. KELLY & GRUZEN, New York City architectural-engineering firm, is in charge of the project.

Conduct your own "Gallup Poll." Ask your friends — any men in the field — if they have ever heard of *a single instance where Vitrified Clay Pipe has ever worn out!* Their answers will speak for themselves.

IF you need specific information on a Clay Pipe problem, write the details to the office nearest you.

NATIONAL CLAY PIPE MANUFACTURERS, INC.

111 W. Washington St., Chicago 2, Ill.
522 First National Bank Bldg., Atlanta 3, Ga.
703 Ninth and Hill Bldg., Los Angeles 15, Calif.
1105 Huntington Bank Bldg., Columbus 15, O.

C-148-2

Vitrified
CLAY PIPE

When writing, we will appreciate your mentioning PUBLIC WORKS

Installing ARMCO Pipe on an important arterial highway in Baltimore, Maryland. Diagonals connecting to the longitudinal drain were placed at 100-foot intervals in a "herringbone" pattern at a 45° angle.

Bumps get "Booted" in Baltimore

Motorists have that "new feeling" in Baltimore. City engineers are eliminating rough, bumpy streets by making sure that new pavement is placed on a dry, stable foundation. Where harmful groundwater is encountered it is quickly eliminated by an adequate subdrainage system.

Installing ARMCO Perforated Pipe to stabilize subgrades not only assures smoother rides but also saves taxpayers' money in longer pavement life and less maintenance expense.

Durable ARMCO Pipe is easy to handle, easy to install. Unskilled workmen quickly join long lengths with sturdy band couplers. Shifting soils and severe frost action are no hazards. Your subdrainage system has *proved strength* to resist crushing, cracking or disjointing under the impact of heavy loads.

Use ARMCO Perforated Pipe wherever underground water is wrecking pavements and sabotaging your budgets. You'll profit in reduced maintenance and the motoring public will thank you. Write for complete information. Armco Drainage & Metal Products, Inc., 2035 Curtis Street, Middletown, Ohio.

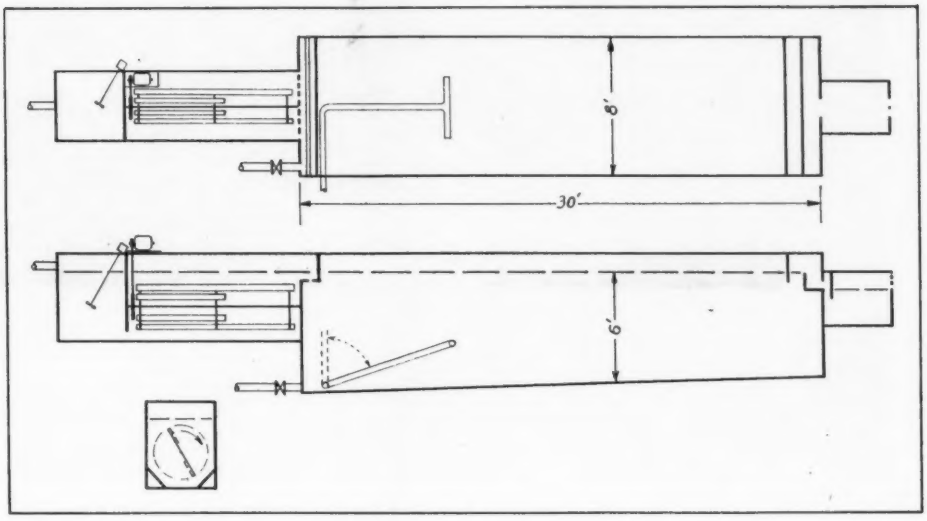
Wet and unstable subgrades lead to patched pavements and rough rides. The only permanent cure is to drain the water out and keep it out. ARMCO Perforated Pipe does this.

ARMCO PERFORATED PIPE

ARMCO

PUBLIC WORKS MAGAZINE . . . April, 1948

VOL. 79. NO. 4



Plan and section of pilot plant showing, left to right, the mixing, flocculating and settling compartments, and effluent weir box.

A Pilot Plant for PULP AND WASTE WATER TREATMENT

CHRISTIAN L. SIEBERT
Consulting Sanitary Engineer,
Camp Hill, Pa.

A PILOT plant for the experimental treatment of pulp and paper waste waters was designed for the Johnsonburg, Pa., mill of the New York and Pennsylvania Co. This plant was constructed last spring and has been operating since about June 1 on the treatment of general mixed waste, with and without the addition of de-inking wastes, which are now discharged and treated separately. The project has been conducted with the full cooperation of the National Council for Stream Improvement. This organization has had an engineer in resident charge, and the final report of operations will be prepared and released by the Council.

The plant has performed exceptionally well, after minor modifications. The principal change was the installation of a tray fitted with longitudinal separating strips to correct the "spin" imparted to the wastes by the flocculating equipment, and which could not be satisfactorily controlled by the adjustable plates over the influent slot to the settling compartment. I had designed the plant to fit the available space in a building, but would prefer to have the flocculating device at the side of the settling compartment and with the right-angle delivery therefrom to the influent trough of the settling compartment, controlling the effect of the "spin" in this way.

The design basis for a flow of 60 gallons per minute included the following: *Mixing compartment*: A detention of slightly less than 8 minutes, which could be reduced if the type of construction used permitted it; a flash mixer was used, which could be replaced with a paddle agitator with a peripheral speed of 3+ ft. per second. *Flocculating Compartment*: A detention period of 20 minutes; tapered slow mixing, with a peripheral speed of 60 ft. per minute; and channel and orifice velocities of 2+ inches per second. *Settling Compartment*: Detention time, 3 hours; displacement velocity 2 ins. per minute; gallons per day per square foot of tank area, 360; square feet of tank area per ft. of weir length, —32 ft.; gallons per 24 hours per ft. of weir, 5,760; proportion of length to width, 3¾:1; depth, average 6 ft.

The flocculating equipment was arranged to operate at varying speeds, both above and below the design factor, but 1 ft. per second appeared to be generally best. The plant was operated at detention periods of 1 to 4 hours; with the waste waters in question, the 2-hour rate gave results practically as good as 3 hours; and there was no improvement with 4 hours.

Treatment with several coagulants was tried but was found not to be de-

(Continued on page 32)

Fig. 5. The artist shows a unidirectional airport close to a large city.

AIRPORT OPERATIONAL SAFETY

Better airport design is needed to reduce the seriousness of many of our airplane accidents.

EDWARD PAYSON HALL
Airport Design and Planning Consultant

ALTHOUGH our airline accident record has shown continued improvement, year after year, no one connected with aviation can afford to forget the all-important consideration of safety. There is reason to hope that future improvements in airplanes, equipment and ground facilities will ultimately lead to a safety record for the airlines that will equal or surpass that of the safest means of transportation yet developed. Achievement of this goal requires the coordinated efforts of the airlines, the airplane manufacturers, the specialized equipment manufacturers, the airport designers and the communities sponsoring airport development.

Publicity on airplane accidents emphasizes the spectacular aspects and frequently gives erroneous impressions to the public. These firmly rooted fallacies are not borne out by the facts. During 1946, the last year for which complete records were available at the time of preparation of this article, another new record was made in domestic passenger operation of only 1.24 passenger fatalities per 100 million passenger miles. Also, due to sensational publicity on the spectacular accidents in which an airplane flies into a mountain, the impression has been created that this is the most common type of accident. This is far from the truth. Of all accidents occurring on scheduled passenger airlines during the 15-year period from 1930 through 1944, 60% involved attempts to land or take-off from airports! (See Figure 1.)

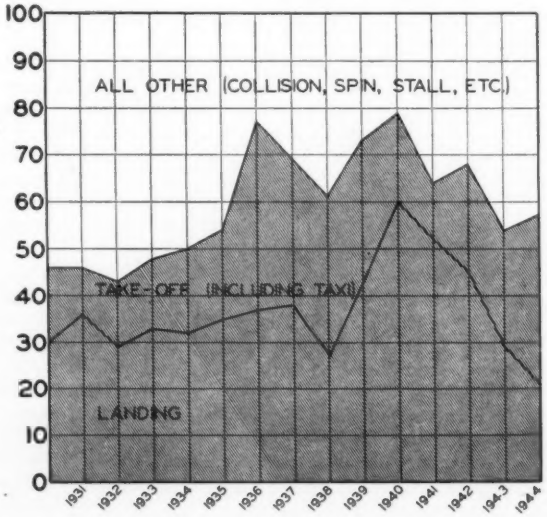


Fig. 1. Nature of accidents. Scheduled domestic airlines.

Many accidents are attributed to errors of judgment or technique on the part of the pilot involved. But make no mistake about the calibre of our airline pilots: they are the best in the world! Careful selection from the upper strata of the piloting profession, rigorous specialized training by the airlines, and periodic medical and proficiency checks all contribute to assure the public that the crews flying our airliners are, and will continue to be, as capable as is *humanly possible*. No human being, however nearly perfect, is infallible: human errors will continue to occur! The real question to face is *what can be done to permit pilots to err and still not have serious accidents?* The fact that our pilots are so capable precludes the likelihood that much improvement can be expected in pilot proficiency but continued recurrence of any one type of accident indicates a definite shortcoming in equipment, facilities or operating procedures.

CAB Accident Records

Detailed examination of the Civil Aeronautics Board records of all scheduled airline accidents for 1945 and 1946, the last two years for which complete records are available, shows that 60% of all accidents occurred while attempting to land, while taxiing, or while taking-off from an airport. Landing accidents accounted for 40% of all accidents, while taxi and take-off accidents accounted for 20%. It is interesting to note that in-flight accidents involving collision with terrain and other aircraft amounted to only 15% of the total.

The great preponderance of accidents at the airport should make the airport designer pause to consider whether or not the airport itself may be at fault. To evaluate such a possibility, it is necessary to analyze the records of the Civil Aeronautics Board in detail and eliminate from consideration those accidents that have little or no relation to landing and take-off facilities. Such an analysis has been prepared for the past two calendar years and is presented in Table I Accidents involving collision with terrain, other aircraft and en route obstacles (high tension wires, trees, etc.) have been eliminated as well as other miscellaneous en route accidents involving hail, fire, engine failure, mechanical failure, etc.

Table I shows that of the three classes, landing accidents are not only more numerous but far more serious. Figure 3 shows the percentage breakdown of

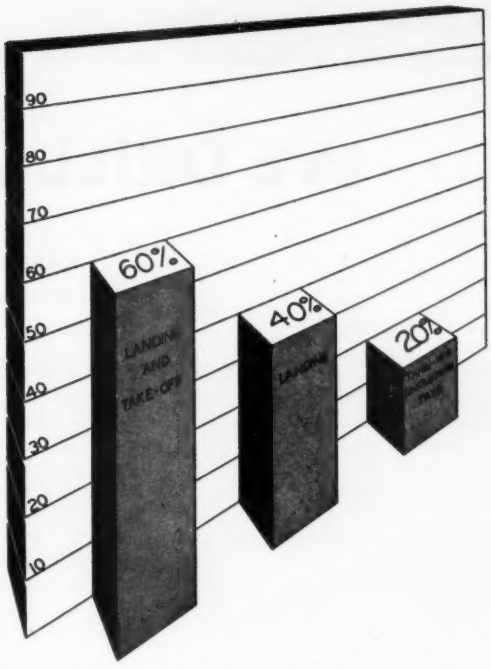


Fig. 2. Airport accidents in per cent of all accidents, 1945-1946.

landing accidents by type. Accidents due to mechanical failure, unlocked landing gear, ground loops and gusts can be eliminated without further consideration as being beyond the control of the airport designer. All other landing accidents however, must be carefully scrutinized to determine in what way improved airport design might reduce the number and severity of landing accidents.

Missed Approaches

Accidents involving missed approach have been most serious and have resulted in fatalities to 28 persons, serious injury to 25 and minor injury to 48. All the airplanes were completely demolished. All four crashes fall into the same general pattern and the wording of the Civil Aeronautics Board summary of

(Continued on page 92)

	ACCIDENTS		PERSONNEL (CREW, PASSENGERS)						AIRPLANES			
			Number			% of Total			Number		% of Total	
	Number	Per Cent of Total	Fatalities	Serious Injury	Minor Injury	Fatalities	Serious Injury	Minor Injury	Destroyed	Major Damage	Destroyed	Major Damage
Landing	30	41.1	34	44	100	18.6	74.6	71.4	9	21	47.4	42.0
Taxi	11	15.1	0	0	0	0	0	0	0	10	0	20.0
Take-off	3	4.1	0	0	1	0	0	.7	0	3	0	6.0
Total Landing, Taxi and Take-off	44	60.3	34	44	101	18.6	74.6	72.1	9	34	47.4	68.0

Table 1. Landing, taxi and take-off accidents, 1945-1946.

Space limited . . . Bids too high . . .
Materials scarce . . . Read

WE DRILL A NEW WELL

CARLTON M. ROBERTS
Formerly Dir. of Public Works and City Engineer

THE city of Asbury Park (N. J.) unlike most cities does not have its pumping station and well field within the city. They are all located in the adjacent township of Neptune, approximately half a mile from the city limits. Since this field has been used some 60 years and approximately 20 wells have been drilled on a plot of ground 260 ft. x 160 ft., it was necessary to find a new location to drill this new well and still be able to use the settling basin and pumping facilities of the pumping station. A survey of the vacant land in this vicinity was made and a site was decided upon where the well would be approximately 600 ft. from our property. It was then necessary to set up the legal procedure for purchasing this property and obtaining the required right of ways for the connecting main. This was finally completed in November, 1946.

19 Pages of Specifications

The usual 19 pages of specifications for a well of this kind, including pumping equipment and a connecting main, were prepared and an advertisement for the proposed work was inserted in our local newspaper, stating that bids would be received for 3 items covering the work called for in the specifications. It might be interesting to note at this point, that in the advertisement the right was reserved to reject any or all bids and also to accept any or all of 3 parts of the proposal, because as will be brought out later, a court case developed from the wording of the advertisement. On the appointed day, two contractors submitted bids on the 3 items of the proposal, each contractor submitting upon a bid form supplied by the engineering department of the city. Unfortunately, the bids were slightly higher than anticipated and since we did not have the required funds in the budget for the 3 parts of the bid, we recommended to Council that they award to the low bidder Item #1, which was under the amount of the total appropriation. This happened in the latter part of December when it was only a matter of waiting a week until we would be operating under an emergency budget, at which time we would be able to award the other 2 items, to be taken care of in the permanent budget for the new year. At a subsequent meeting, the first one in January, the Council awarded the contract to the low bidder on Item #2 and Item #3. The listing for the 2 bidders is as follows:

	Contractor "A"	*Contractor "B"*
Item #1	$21,246	$21,300
Item #2	2,124	2,600
Item #3	3,950	2,900
	$27,320	$26,800

It can be seen from these figures that had we asked for a lump sum bid the total job would have cost the city $26,800 and Contractor "B" would have been the low bidder, whereas by awarding Items 1 and 2 to Contractor "A" as low bidder and Item 3 to the Contractor "B" as low bidder, the total job cost $26,270 or a net saving of $530 on the contract. Because of the awarding of the contracts in accordance with this method, Contractor "B" started suit in the State Supreme Court for the issuance of a writ of certoriari, to set aside the awarding of the contracts in this manner and contended that the city should award the entire contract to them on the basis that they were the low bidder on the 3 items. The State Supreme Court upheld the action of the city in its method of advertising and awarding the contracts.

The CPA; the WAA; and No Luck

After the contracts for Items 1 and 2 were signed and a satisfactory bond furnished, we found that there was a scarcity of 12-inch steel pipe which was to be used for the casing. We thought that the Civilian Production Administration would be able to give us a lead in obtaining this material, since a number of feet of this pipe was being held by suppliers waiting for approval of release from the office of temporary controls of the CPA. We contacted this office in Washington, D. C., told them our story and asked them for a priority. Later, we received a letter from them stating that we should investigate the possibility of obtaining this material from the surplus property controlled by the War Assets Administration, since they had no authority to give us a priority for the pipe. We then contacted our Senator regarding this material and he put us in touch with the proper person in the War Assets Administra-

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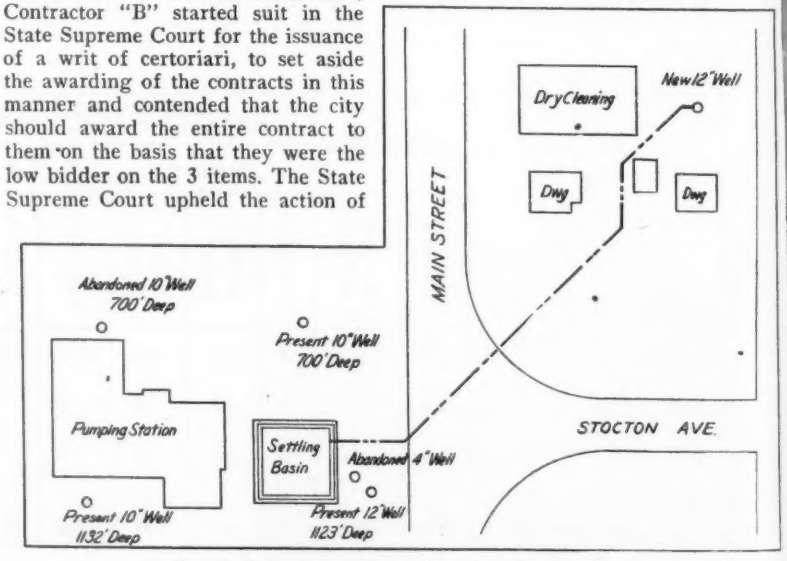


Layout of pumping station and location of new well.

Expediting Paving and Drainage By Force Account

How a city, in order to expedite a street improvement program, built curbs and gutters and laid hot-mix surfacing.

R. E. EDMONDSON
City Manager

MONTROSE, COLORADO, like any town or city, presents particular problems which of course are not duplicated in entirety in any other city. Recently the city voted street improvement bonds to surface-drain the city by the installations of curb and gutter, and to pave the streets with bituminous materials in a drive to get out of the mud.

This was, of necessity, up to the city forces and equipment to accomplish. To have done the work by contract would have required a long delay, due to the field surveying and office design necessary to estimate quantities and prepare plans and specifications for intelligent bidding. The public, having voted for the project, was in no mood to wait very long for a start.

"With Fingers Crossed—"

With fingers crossed and an eye on war assets surplus, the job got under way. Our streets are 100 ft. wide overall, with a 5-ft. sidewalk 2 ft. from the property line, and the curb line 18 ft. from the sidewalk. This gives a 25-ft. curb line and a 50-ft. wide residential street. Commercial blocks have a 75-ft. clear street with the curb line 12-ft. 6 ins. from the property line.

The first step in construction was the installation of curbs and gutters. The gutter was made 2 ft. wide with a 7-inch curb. Lines running north and south in general were worked out to a 1% grade. East and west lines were a different story; generally a 0.3% grade was possible, with drainage toward the northwest or diagonally across the city. On some east-west blocks the grade had to be broken in the middle of the block and taken each way to meet the north-south drainage. In order to get the general drainage it was necessary to run profiles on all streets; and it was, of course, necessary to know flow line elevations entering and leaving any given block before curb and gutter could be installed in that particular block.

Courtesy The Texas Co.

Mixing cutback on a job similar to that at Montrose.

Drainage being a "must" it was necessary at times to ignore sidewalk and yard elevations. In some cases, yards and walks were "up" and in other cases "down." When these were below the top-of-curb elevation, valley drains were used at intersections. When these were above the top of the curb, corrugated metal pipes were installed at intersections for cross drainage. Alley intersections were all of the valley drain type. Property line boundaries, extended, were marked in the top of the curb at the street corners thus serving as a permanent reference to the corner.

A 3-inch sand cushion was put in and wetted and rolled before curb and gutter forms were placed. A class "A" concrete mix was used; this varied slightly from time to time, depending on temperatures and changes in the product at the aggregate pit. Every effort was made to control the recommended screen sizes of crushed rock as produced at the city yard. A field laboratory was set up in the tool house at the crushing plant so that tests could be taken at intervals.

Excess dirt from curb and gutter excavation was used to back-fill behind the curbs when the forms were removed and to build up low parkings. Back-fill for the face of the gutter was ¾" maximum size, graded crushed rock surfacing. This saved time later on when the streets were subgraded. Waste dirt was hauled to low streets that needed grade raising.

Subgrading Problems

Following the curb and gutter, subgrades for the street were next, and here some difficulty arose. The surplus equipment set-up had changed priorities and we needed something to move dirt. There was on the street a great deal of old river run gravel, placed there under a previous project. This made very good select material but was out of the question to lay oil mat on. We didn't want to waste this valuable product but wanted to lower the dirt under it. Without the facilities to do this, we decided a high crown would have to be the answer. The existing street was therefore bladed and graded uniformly and a course of ¾" maximum size graded crushed rock surfacing was laid over this. The "must" for this operation was at least 6 inches of subgrade, as with our adobe soil, tests showed at least 6 inches of stabilization necessary for

(Continued on page 32)

Small Sewage Treatment Plants

III—Sludge Digestion and Disposal

This series began in the February issue. The first article discussed general factors in small plant design, and the second the problems of primary settling tank design. These articles are intended to help solve the problems of the 9,058 small communities reported by the Public Health Service to be in need of sewerage facilities.

IN the small plant, adequate provision must be made for sludge treatment and disposal. It is not often possible to base the required sludge digestion capacity on an analysis of the solids content of the sewage. Empirical methods of design are generally necessary; and this may often be on the basis of so many cubic feet of sludge digestion tank capacity per person. There is also the problem of whether or not the tank is to be heated. In the very small plant, heating may not be necessary; but in such cases considerable excess digestion capacity should be provided, especially in northern areas. Heating is nearly always desirable in colder areas, not only to assure better operation but also to prevent possible freezing.

Sludge Storage Capacity for Imhoff Tanks

State sanitary engineers have prepared requirements or recommendations for the capacity, in cubic feet per person, that must be provided in the lower portion of an Imhoff tank when used for primary treatment. This capacity must be provided below a plane 18 inches beneath the point where the full overlap at the slot of the settling compartment is effective.

A number of state requirements have been examined. The capacity that should be provided per person varies from 2 cu. ft. (in the absence of secondary sludge) in Alabama to a preferred 4 to 5 cu. ft. in South Dakota. Not all of these regulations are entirely clear as to whether or not secondary treatment is included. Colorado recommends 3 cu. ft. per person and assumes secondary treatment; Connecticut has found 3½ cu. ft. per person to be generally satisfactory. Idaho states that at least 3 cu. ft. should be provided per person for the design population. Iowa requires a greater capacity for plants in the northern part of the state, 3½ cu. ft., than in the southern part, 3 cu. ft. Kansas, New York and New Mexico recognize that smaller plants require greater capacity and their recommendations are: Kansas, 4 cu. ft. for plants serving less than 1,000 population and 3½ for larger plants; and New York and New Mexico 3 cu. ft. for small plants and 2 cu. ft. for larger plants. The minimum in South Dakota is 3 cu. ft., but 4 to 5 is recommended.

Geography, or rather climate, is undoubtedly important. The northern areas should have a greater digestion capacity because there is but a short period of rapid digestion; during the remainder of the year, the sludge temperature is likely to be too low for much effective reduction. A capacity of about 3 cu. ft. per person in warm climates and upward of 4 or 4½ cu. ft. in cold areas appears most desirable.

Sludge Digestion with Separate Settling

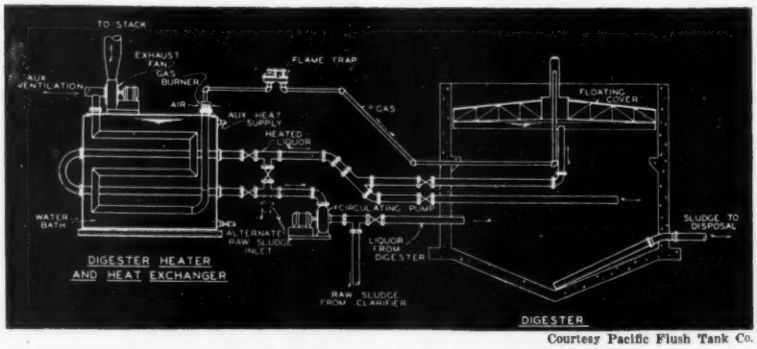
Recommendations or requirements are available from a number of typical states regarding the capacity of digesters, in cu. ft. per person, for the various methods of sewage treatment. Some of these are tabulated in Table I.

If provision is made for heating the tank and otherwise conditioning the sludge, Alabama will give consideration to a reduction in digestion capacity below 2 cu. ft. Kansas requires a minimum of 3 cu. ft. for heated digesters with trickling filters and air-drying of sludge; with unheated digesters, "substantially larger per capita capacities should be provided." In New York, "where the population exceeds 3,000 and suitable provision is made for heating the tanks, the above capacities (3.0 to 4.0 cu. ft. per person) may be considerably reduced." In South

Table I.—Capacity of Digesters in Cu. Ft. Per Capita

	Pri.	Tr. Filt.	Act. Sl.
Unheated			
Ala.	2	...	...
Colo.	3	4	6
Conn.	3½	4½	4½
Fla.	2	3	5
Idaho	3	4	6
Kansas	...	@	...
N. Y.	...	...	...
S. Dak.	...	...	...
Tenn.	2½	...	...
Texas	2½@	3 to 4@	5@
Heated			
Ala.	@	...	...
Colo.	2½	2½	3½
Conn.	2	2½	4
Fla.	...	...	...
Idaho	2	2½	3½
Kansas	...	3	...
N. Y.	...	3 to 4@	...
S. Dak.	2½@	3½@	...
Tenn.	3	...	...
Texas	...	...	...

@—See text for further data.



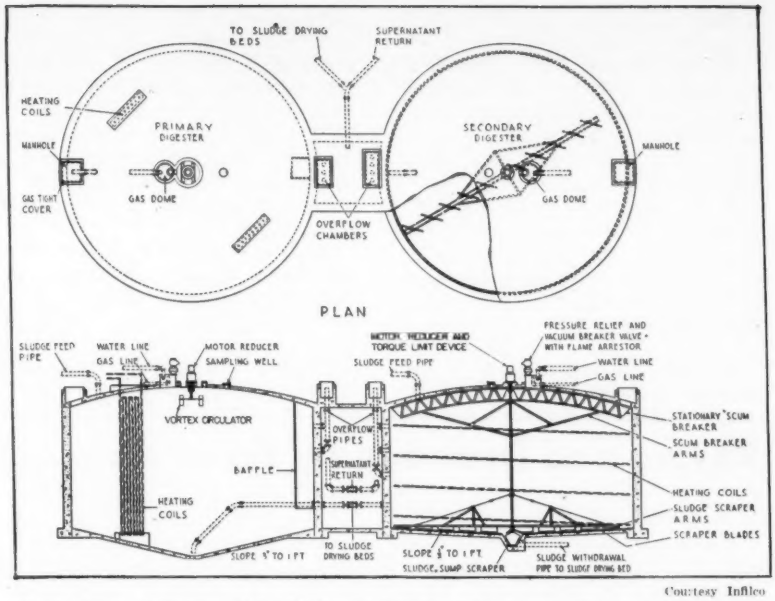
Courtesy Pacific Flush Tank Co.

Digester with floating cover and outside heat exchanger.

Dakota, "digestion tank capacity may vary from 2½ to 6 cu. ft. per person, depending on the type of plant and other considerations . . . For trickling filter installations, the digestion tank capacity should be 2½ to 3½ cu. ft. per capita of designed capacity. In special instances, less capacity will be considered." The Texas figures do not specify that tanks shall be heated, though the text of the bulletin indicates that this is considered desirable.

It should be noted that these figures are for plants of normal size, and that in the few places where specific reference is made to small plants, a greater capacity per person is required. In the past, many digestion tanks have been inadequate in capacity. It is believed that not less than 3 cu. ft., and preferably 4 cu. ft. per person should be provided in heated digesters serving small plants; and at least 50% should be added to these capacities for unheated tanks. These capacities may apply with either primary only or primary and secondary treatment.

On this basis, assuming a population of 750 persons for design purposes and primary treatment only, a heated tank, 3,000 cu. ft. of capacity should be provided. This would require a circular tank 16 ft. in diameter and about 16 ft. deep. Digester mechanism for a tank of this size can be supplied by most manufacturers. Dorr and Infilco, for instance, make digester mechanisms for units as small as 10 ft. in diameter. Link-Belt makes a scum-breaker mechanism especially suited for small jobs. An installation of this type at Waverly, Va., was illustrated in the March issue. This equipment fits into a rectangular tank placed alongside the settling tank. Other makers of mechanism for digesters include Pacific Flush Tank, Carter, and Hardinge.

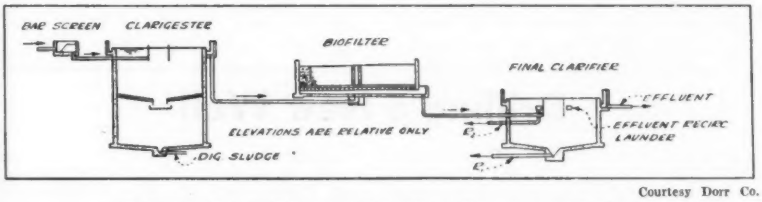


Courtesy Infilco

Simpler types of digesters, but with the advantages of the larger units are available for small plants.

Heating Calculations

Requirements for heating are subject to quite exact analysis but for the purpose of this article, approximate methods will be followed in order to illustrate the utilization of sludge gas for the purpose. The principal reason for using heat is, of course, to provide for more rapid and complete sludge digestion, permitting a reduction in the size of the digester. Heat is necessary to raise the temperature of the sludge pumped from the settling tank into the digester, and to maintain the temperature of the sludge in the tank against heat loss by radiation through the walls and cover of the tank.



Courtesy Dorr Co.

Clarigester installed in connection with a filter at a small plant.

The per capita volume of sludge in the small plant is variable; and for that reason it will be assumed, for the purpose of calculating heat requirements, that in this instance, it will amount to 500 gallons per day for the 750 persons; and that the digester is circular, 16 ft. in diameter and 16 ft. deep.

If the digester is to be maintained at 90°F and the average temperature of the sludge drawn from the settling tank is 50°, representing the average of conditions for the coldest 2-week period, the heat required to raise the sludge from 50° to 90° will be: 500 x 8.34 x 40, or about 167,000 btu.

The roof area of a 16-ft. diameter tank will be 201 sq. ft. The bottom area will be the same. If allowance is made for a sloping bottom, the bottom area will be about 210 sq. ft. The sides of the digester should be banked with dirt, or covered with tile providing an air space, so as to reduce heat loss.

Assuming the average of the coldest two weeks to be 10°F, and a radiation loss of 48 btu. per sq. ft. per 24 hours, from the cover, the total loss will be 201 x 48, or 965° btu. The loss from the bottom will be less, because the soil temperature may be assumed at 45°F. and may be assumed at 5 btu. per sq. ft., or 210 x 5, or 1,050 btu. The side walls are assumed to be well banked or otherwise protected to prevent loss of heat. The probable loss from such walls is about 9 btu. per sq. ft. per 24 hours. The side wall area will be 16 x 3.14 x 16, or about 800 sq. ft., and the total loss will then be 9 x 800 or 7,200 btu.

The total of all losses for a 24-hour period is 167,000 + 9,660 + 1,050 + 7,200, or 184,910 btu. The average hourly loss is about 7,750 btu. To this should be added a safety factor to care for other losses, which will aggregate about 25% of the losses from the roof, bottom and sides, or about 180 btu. per hour. Thus the total requirement will be close to 8,000 btu. per hour. This can be supplied by the gas produced by sludge digestion. Normally, this will aggregate about 0.8 cubic feet per person per day; with a btu. content of 650 per cu. ft., the available heat will be about twice what is needed to heat the digester, less the loss due

to heat escaping in a boiler which is about 80% efficient.

If water at 130°F is used to heat the digester (this is about as high a temperature as should normally be used), the computation for piping or other heating will take this form: Water in, 130°, and out 110°, average 120; digester temperature, 90°; difference 30°. Dividing the 8,000 btu. required for heating purposes by 30, there will be required about 270 pounds of water per hour, about 4½ pounds per minute, of 0.6 gal. per min.

Assuming a radiation from the hot water pipe of 20 btu. per sq. ft. per degree per hour, the heat radiated from one sq. ft. of pipe surface per hour will be 30 x 20, or 600 btu. The pipe area required will be 8,000 divided by 600 or about 14 sq. ft. With 1-inch pipe, this would require about 40 ft. The pipe can be arranged peripherally, around the tank, or as a coil; or an outside heat exchanger can be used.

The above data are general in nature, and designed only to illustrate the overall methods without reference to the refinements normally used in design. They do indicate that heating is possible and desirable even in the small plant.

Paving and Drainage by Force Account

(Continued from page 29)

a satisfactory subgrade. The high crown has not been particularly disadvantageous to traffic. We have found that it is an advantage in getting water to the gutters in a hurry, whereas some of the old flatter streets have developed cups which hold the water and cause trouble.

The flow line elevations on each side of the street generally were of the same grade but not necessarily the same elevation. This produced a roadway crown in most cases of unbalanced parabolic form.

With a completed street, with curb and gutter properly placed, and a shaped subgrade we were ready for the 2-inch bituminous paving.

Paving Details

Two 16,000-gal. oil storage tanks were owned by the city. These, which were unmounted, were set on concrete piers and a sump dug at one end. The oil distributor tank was backed into the sump and a 6-inch gate valve was opened, filling the distributor in 5 minutes where the old method of pumping had taken 35 minutes. MC-5 asphalt was used for the mix and seal coat; and MC-1 for prime. A Barber-Greene hot mix plant was used for mixing. The aggregate was first dried and heated to a temperature of 300°F, then mixed with the hot oil. Thence it was handled by conveyor to dump trucks and to the street.

The most practicable way we found to control the amount of mix per truck was for each driver to strike off his local level. The capacity of the truck and the compaction in place for the mixture being known, each truck was given a card stating the distance that this load was to spread. The driver measured this on the street.

The windrow of oil-mix was spread with a grader as the mix for each block was placed. Traffic was kept off the street during this process; and, in fact, was not permitted until the street had been thoroughly rolled with an 8-ton tandem roller. Later, the oil mat was sealed with MC-5, and chips, ⅜" to No. 10, were immediately placed and well rolled into the mat. Excess chips were removed from the mat in about three weeks.

I have found that a careful explanation of all questions asked is apparently satisfactory to the public, and in spite of high costs the general reaction is that they still want the job completed. Curb and gutter runs $1.47 per lineal foot. Bituminous paving $2.18 per lineal foot.

Pilot Plant

(Continued from page 25)

pendably advantageous, even with fantastically high dosages, because of fluctuations in the character of the wastes; and also because of the presence of some sulphite liquor in varying proportions.

Plain sedimentation has so far appeared to be capable of reducing settleable solids by averages, from about 15.6 ppm. to 0.3 ppm., or 98%; and has produced an average reduction of total suspended solids from 283 ppm. to 71 ppm., or 75%. Reduction in BOD with plain sedimentation has so far been, by averages, from 286 ppm. in the raw to 244 ppm. in the settled, or 14.7%. Chemical treatment produced average results poorer than did plain sedimentation. The volatile suspended solids in the raw wastes averaged slightly greater in weight than did the non-volatile.

These data are preliminary and should not be accepted as authoritative, as the experimental operation of the plant is to be continued for several months. The final report will be prepared and issued by or under the direction of Dr. Harry Gehm.

Drilling a New Well

(Continued from page 28)

tion, who said he was very anxious to help us and would try to find the required feet of pipe, but actually did nothing to help us at all. As a matter of fact, we saw an advertisement in the Philadelphia papers, where the WAA was placing on sale, to the highest bidder, some 10,000 feet of the pipe mentioned. We immediately telephoned the WAA in Washington, requesting that they withdraw 1,200 ft. of this pipe from the above mentioned sale and stating that we would be willing to pay the market price for this pipe since this was a project involving the health, sanitation and fire protection of our city. We were told that if we wanted this pipe we would have to be present at the sale and compete with the other bidders for the entire amount of pipe. As you can see, we were not in a position to pay for a large quantity of pipe and had no need for the same, therefore did not attend the sale. However, the contractor, on scouring the eastern section of the country, was able to come up with some 200 ft. of 12¾-inch, 325 ft. of 13⅜-inch, 500 ft. of 14-inch pipe, which we eventually used for the casing.

The Work Starts

Due to the holdup on finding the casing, we were unable to start actual drilling until June. We started first by drilling a 24-inch hole to approximately 80 ft. below the surface and set a 20-inch casing pipe to prevent cave-ins and the admission of surface water to the well. We then drilled a 17-inch hole down until we had reached the Raritan strata, which started at approximately 1085 ft. below the surface, and continued drilling to 1138 ft. below the surface. We then set the casing to the top of the Raritan Strata before starting the under-reaming. After the casing had been set and before under-reaming had started, we grouted with cement and forced this on the outside of the casing from the bottom towards the top, from above 1085 ft. to 885 ft., and also from the surface down to 200 ft. below the

surface. We then started our underreaming operation to 36 inches in diameter from approximately —1100 to —1140, which gave us 40 ft. of the Raritan strata available for the well.

The Well Produces

We then set 30 feet of 8⅝-inch in diameter slotted Emsco screen which is wrapped with stainless steel bars welded in place. We then packed the gravel in the well; this was done while the column of pipe which lowered the screen and held it in place was still in the hole and the gravel was fed between the two casings. We then removed the column and built a base around the surface casing in order to test the well. Since the electrical installation had not been made, we tested the well by the airlift method, using 3 compressors. The discharge was placed approximately 10 ft. above the surface and emptied into a 1000-gal. tank, which discharged through an 8-inch pipe with a 6-inch orifice. By continually turning on the compressors and shutting them off again, we were able to clear up the well in a matter of a few days, when there was no perceptible sand present. On the first test, using the air compressors and running for a period of 2 hours, the well produced water at the rate of 1,300,000 gallons per day. We felt that this test would indicate that with the proper pumping equipment we would produce considerably more water.

While we were drilling the well, we were getting quite concerned that Contractor "B" had advised us that they would not accept the contract for laying the connecting main, since they did not receive the other 2 parts of the project. Therefore, it became necessary to re-advertise this part of the contract, which we did, receiving higher bids than originally. We then entered into a contract with Contractor "A" to install the connecting main to the aerator. A dry cleaning plant was being constructed at this time, and they had to ask our permission to pass through our property with their sewer line; also the people on the south of our property were using 3 ft. of the southerly part as a driveway and entrance to their garage, so we had no difficulty in obtaining easements for our connecting main. We then started the construction of the connecting main, running our electrical conduit in the same trench; and in the meantime constructing the permanent base for the deep well turbine pump. After the connecting main and conduit were completely installed, we erected a pole adjacent to the pump for our switchbox and ran a test of the pump and the production of the well, by pumping the water through our aerator to our settling basin. This test showed that the well produced at the rate of 1,600,000 gallons per day.

The contractors have now engaged the Pitometer Company to make the final test on the well production. In accordance with the contract, the contractor will be paid a bonus for producing water in excess of the amount guaranteed. The entire contract with the exception of the bonus has been accepted and the contractor paid. It must be noted, at this point, that in order to drill a well of this size and to divert this quantity of water from the underground strata, it is necessary to obtain permission from the State Department of Conservation, Division of Water Policy and Supply.

A High-Rate Filter for a Small Community

PLANS prepared by the Caldwell Engineering Company of Jacksonville, Illinois, for a complete sanitary sewage treatment plant for the city of White Hall, Illinois, were approved by the State Sanitary Water Board June 12, 1946, and construction begun the latter part of 1947.

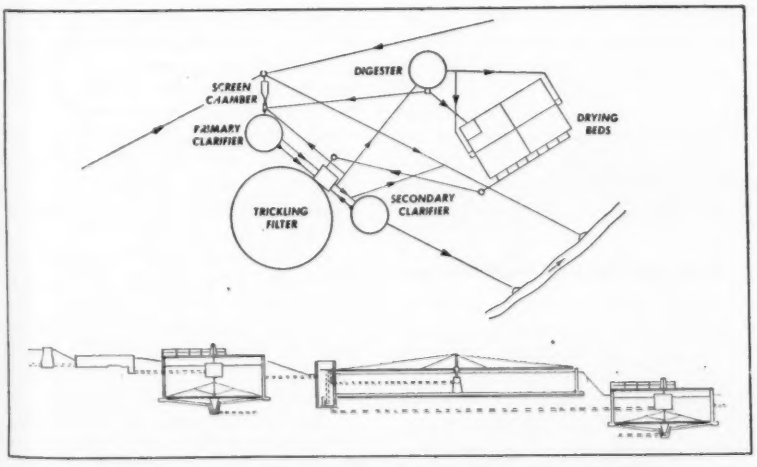
The plant is designed on a basis of 4,000 population. The primary settling tank has a retention period of 2½ hours with an expected BOD reduction of 35%. This tank is 30 ft. in diameter, as are the secondary settling tank and the digester. It is equipped with Infilco WS clarifier mechanism, an automatic hydraulic skimming device and an automatic scum valve for removing floating material.

The plant has been designed around the Accelo-Filter, and recirculation is provided. The effluent from the primary tank is received at a control well. There it is mixed with recirculated effluent and applied to the trickling filter. The filter is designed for 1:1 recirculation of the filter effluent, which not only permits the use of a smaller diameter bed, in this case a reduction in diameter from 104 feet to 86 feet, but also results in increased biological filter efficiency, and elimination of odor, gnat and fly nuisances.

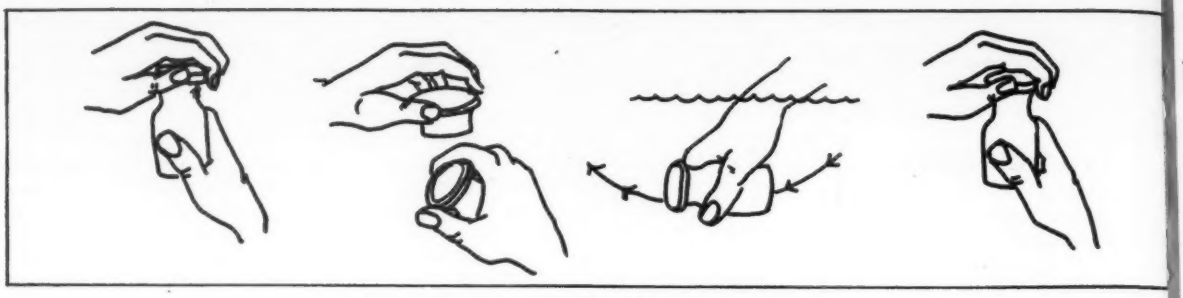
The most distinct advantage, however, is the flexibility in plant capacity, which permits handling heavy loads without additional increase in the size of the sedimentation tanks. The filter is to be equipped with an Infilco rotary distributor. Recirculation is accomplished by means of two vertical close-coupled Fairbanks-Morse sewage pumps, each with a capacity of 556 gpm. These may be operated either singly or in parallel.

The secondary settling tank is designed for 2 hours retention. It is equipped with an Infilco WS clarifier mechanism. Secondary sludge may be returned to the primary tank or pumped directly to the sludge digester as desired by the operator. Both primary and secondary sludge are pumped with a 40 gpm. plunger type simplex sludge pump.

The digester is equipped with an Infilco VC digester mechanism. Provision is made for the collection of sewage gas which will be utilized both for heating the control house and the digester. Supernatant liquor may be returned to the primary tank or passed onto a supernatant bed.



Layout of the White Hall plant, with profile through plant.



Steps in taking a water sample from a lake or stream.

The OPERATION *of* WATER TREATMENT PLANTS

This text was first issued ten years ago. Designed for operators and superintendents everywhere, but especially in the smaller plants, it has been a standard supplementary instruction text. Its usefulness has been attested by the many thousands of reprints, issued both by us and by others, in this country and overseas. It was a primary source in the preparation of the Army water works operation manual.

This third edition, which has been completely revised and rewritten, is especially intended to meet post-war conditions and to assist the many thousands of newcomers to this field.

Outstanding engineers have aided in preparing this material, both by reading the original text and suggesting improvements, and by discussing the general subject with us. We regret that the list is too long to include here. Our readers and students will join us in thanking them for their very great assistance.

THIS text is designed primarily to provide a simplified approach to, and a background for, standard texts on water works operation. It may also be used for on-the-job training, or as an outline for home study. In any case, as many standard water works texts as possible should be available to the student. The following list represents the minimum he should have:

(1) Standard Methods of Water and Sewage Analysis;

(2) Analyses of Water and Sewage, by Theroux, Eldridge & Mallman;

(3) Water and Sewage Chemistry and Chemicals;

(4) Water Supply and Purification; and

(5) The Water Works Manual.

The Editors of PUBLIC WORKS will be glad to assist in obtaining these texts.

In addition to the above, the Public Health Service Manual of Water Sanitation Practice should be in the possession of every water works operating man. It can be obtained by writing the U. S. Public Health Service, Washington, D. C., and asking for Public Health Bulletin 296.

Methods and Units of Measurement

In water treatment plant operation, including the performance of tests and the use of chemicals, various methods of measurement may be employed. The metric system is utilized generally in laboratory work. In treatment, dosages are computed in grains per gallon (gpg.); parts per million (ppm.); or pounds per million gallons (lbs./mg.). The operator should be familiar with all of these. He should also be moderately familiar with the metric system.

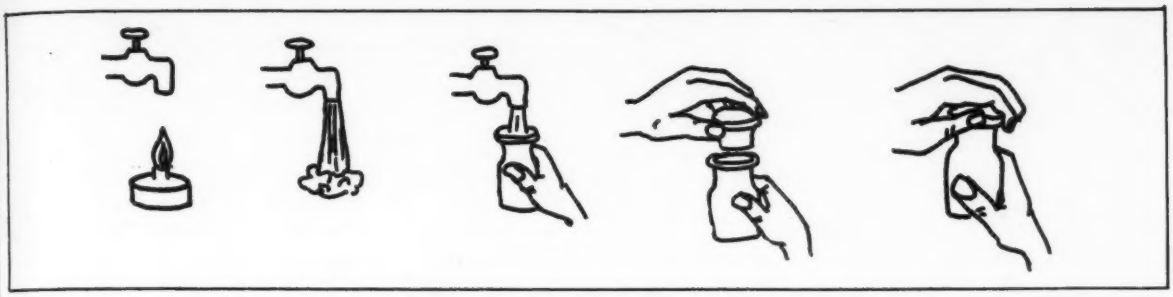
Third Edition, Rewritten

The Metric System.—In the metric system, the standard unit of volume is the liter (slightly more than 1 quart). This weighs 1 kilogram (kg) and is equal in volume to 1,000 cubic centimeters (abbreviated cc.); and also to 1,000 milliliters (ml.), which unit is now generally used instead of the cubic centimeter. Both of these have the same value for all practical purposes.

The standard unit of weight is the gram, which is the weight of 1 cc. or 1 ml. of water. One gram contains 1,000 milligrams (mg.). Therefore 1 mg. per liter equals 1 part per million.

The Centigrade Scale. — In the centigrade (C) scale, freezing is at 0° and boiling at 100°; in the Fahrenheit (F) scale, freezing is at 32° and boiling at 212°.

To change F to C: Subtract 32 from the F reading, divide the remainder by 9 and multiply this answer by 5. *Example:* 95° F. Subtract 32 leaving 63; divide by 9 equals 7; $5 \times 7 = 35°$ C. To change C to F.: Divide by 5, multiply by 9; add 32. *Example:* 20° C. Divide by 5 equals 4; $4 \times 9 = 36$; $36 + 32 = 68°$ F. See also the chart herewith.

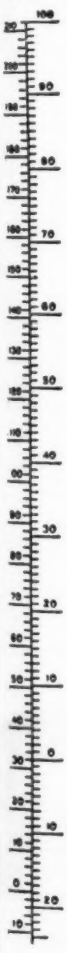


How to take water samples from a faucet.

How to Measure Chemicals.—There are three common methods of measuring the amount of chemicals in water. These are: grains per gallon (gpg); parts per million (ppm.); and pounds per million gallons.

Since there are 7,000 grains in an avoirdupois pound, 1 grain per gallon equals 1 pound in 7,000 gallons; or 1,000,000 ÷ 7,000 = 142.9 pounds per million gallons. A gallon of water weighs 8.34 pounds; therefore 1 gpg. = 142.9 ÷ 8.34 = 17.1 ppm. Thus 1 gpg. = 17.1 ppm. = 142.9 pounds per mg. Also, 1 ppm. = .058 gpg. = 8.34 pounds per mg.; and 1 pound per m.g. = .007 gpg. = 0.12 ppm.

When Imperial or Canadian gallons are used, these figures change. The U. S. gallon equals 0.83 Imperial gallon. One grain per Imperial gallon equals 14.2 ppm. or 119 pounds per million Imperial gallons.



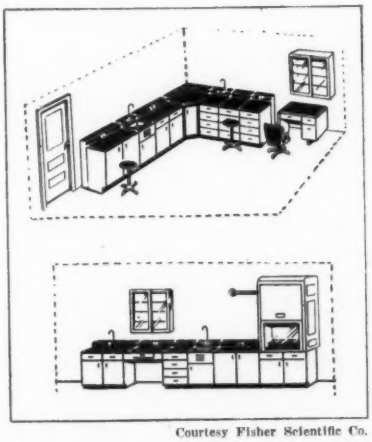
This scale makes conversion from Fahrenheit to Centigrade temperatures easy.

Procedures in Testing

Laboratory Equipment.—A laboratory and laboratory equipment are required for every plant. It is not necessary that the laboratory be large, nor the equipment costly. What is needed depends upon the tests that are to be performed, and these, in turn, depend upon local conditions. A laboratory layout for a small plant and a list of the equipment needed to make the various tests can be obtained from your State Board of Health by addressing the State Sanitary Engineer, or will be furnished by the Editor of this magazine without charge.

In all water testing procedures, the instructions of *Standard Methods* and other reliable texts should be followed in detail. Some of the tests are presented hereafter in a simplified form, including pH, alkalinity and acidity, hardness, and residual chlorine, and certain microscopical examinations. Procedure in bacterial examination will be discussed, but the details and technique of these examinations must be learned through attendance at short schools or other courses of instruction that are provided in almost every state. Other tests of a similar nature, as those for dissolved oxygen, chlorides, nitrates and nitrites, etc., also should be learned by actual instruction and practice.

Taking Samples for Physical and Chemical Tests.—From 2 to 4 quarts of water (2 liters or more) are required for the usual physical and chemical tests. The water should be collected in special bottles equipped with glass stoppers. Do not use milk or thermos bottles; get containers from the laboratory. These should be cleaned in the laboratory with either alkaline permanganate solution or dilute sulphuric acid and potassium dichromate; dipped in a weak mixture of oxalic and sulphuric acids; rinsed with water and allowed to drain. The sulphuric acid-potassium dichromate solution is prepared as follows: Add 120 grains of potassium (or sodium) dichromate to 1500 c.c. of tap water and dissolve with the aid of heat. Then add 180 c.c. of commercial sulphuric acid.



Courtesy Fisher Scientific Co.

Two of the many methods in which units of laboratory furniture can be combined.

When taking a sample from a stream or lake, the bottle is placed about 18 inches below the surface in order to avoid the surface film. The stopper is then removed, the bottle allowed to fill and the stopper replaced. When taking a sample from a faucet that has been closed, or from a similar source, allow the water to run to waste for a few minutes. If the sample is taken from a pump, sufficient water should be wasted to empty all of the pump connections and to draw water from the well, main or other source. Containers should be filled completely.

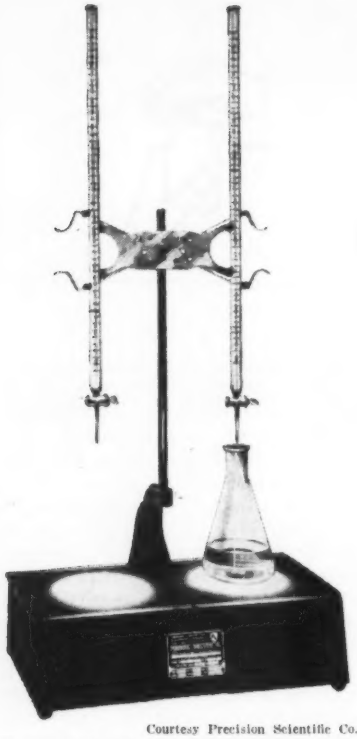
Tests should be made promptly after the sample has been collected. According to *Standard Methods*, examinations may be made on unpolluted water within 72 hours, on fairly pure water within 48 hours and on polluted water within 12 hours. These are maximum limits; shorter elapsed periods are desirable.

Testing for Turbidity

Particles of soil carried in suspension in the water cause a muddy or turbid appearance. Such water is objectionable for general use and must be treated, though turbidity does not affect health.

Permissible Limits.—The upper limit of turbidity that will not cause some complaints from consumers is about 5 ppm.; that is, five parts by weight of solid matter to a million parts of water, but a turbidity of 10 is generally considered permissible.

Methods of Determining Turbidity.—Three methods of testing the amount of turbidity are available. These are (1) by means of the turbidity rod of the U. S. Geological Survey. (2) by means of turbidimeters and (3) by comparison with previously prepared standards. The turbidity rod is used mainly for field determinations; the turbidimeters for



Courtesy Precision Scientific Co.

Fluorescent type burette makes readings easier.

laboratory work. These are described in detail in texts (1) and (2) listed at the beginning of this article.

Determining Color

Color in water is due to material that is in solution in the water, as from decaying organic matter in swamps, where it consists of the tannates, gallates and organic acids from leaves and bark, and from plants. An apparent color is sometimes caused by colored matter in suspension, but true color is in solution.

Permissible Limits.—Color is objectionable, though ordinarily harmless; to avoid complaints from consumers, water should not contain more than 10 parts per million of color.

Determination of Color.—A standard 50 c.c. Nessler tube may be used. This is filled and compared with a series of color standards by placing the samples on a white surface and looking down on them from above.

Color solutions for comparisons may be made by dissolving potassium chloroplatinate and cobaltous chloride in distilled water, but it is simpler to purchase the standards, either in solution form, or as colored glass discs.

When there is suspended matter in the water, removal of such matter must precede the color test. Filtering produces a decolorizing action; removal of the suspended matter by centrifuging is best. For details of procedure refer to the texts already listed.

The Mineral Constituents of Water

Alkanity, hardness, acidity and salinity occur in water due to the presence of certain soluble materials. These qualities are measured by means of several tests which, in some cases, are nearly enough related to each other to cause confusion. A particular example is the broad use of the term "alkalinity," which is employed as the opposite of "acidity" in connection with pH or hydrogen ion tests; and is also used to designate the amount of certain dissolved minerals that the water contains—the bicarbonates, carbonates and hydroxides of calcium, magnesium, sodium and potassium. In this article, *pH* refers to the *intensity* of alkalinity or acidity and *alkalinity* refers to the *amount* of carbonates, bicarbonates or hydroxides that are present.

Causes of Alkalinity.—The compounds in natural water that cause

Courtesy Precision Scientific Co.

The Jackson turbidimeter.

only alkalinity are potassium carbonate (K_2CO_3) and bicarbonate ($KHCO_3$) and sodium carbonate (Na_2CO_3) and bicarbonate ($NaHCO_3$). The following compounds cause alkalinity and also hardness: Calcium carbonate ($CaCO_3$) and bicarbonate ($Ca(HCO_3)_2$), and magnesium carbonate ($MgCO_3$) and bicarbonate ($Mg(HCO_3)_2$).

Causes of Hardness. — Calcium and magnesium carbonates and bicarbonates cause carbonate hardness, sometimes called temporary hardness because some of it can be removed by boiling. The following compounds cause non-carbonate (sometimes called permanent) hardness and also salinity; calcium sulphate ($CaSO_4$) and chloride ($CaCl_2$) and magnesium sulphate ($MgSO_4$) and chloride ($MgCl_2$).

Causes of Salinity.—In addition to the calcium and magnesium sulphates and chlorides, salinity is caused by potassium sulphate (K_2SO_4), chloride (KCl) and nitrate (KNO_3); and by sodium sulphate (Na_2SO_4), chloride (NaCl) and nitrate ($NaNO_3$).

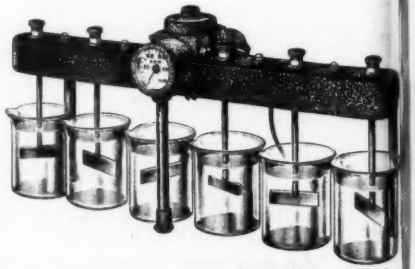
Causes of Acidity.—Acidity in water is caused by free carbon dioxide (CO_2), by various mineral acids, by iron and aluminum sulphates and by other less common compounds.

Equipment for Tests.—Determination of alkalinity and acidity is simple. Necessary equipment includes a burette (50 cc. capacity, with 1/10 cc. graduations, and a stop cock); a burette support; a 100 cc. cylinder; 6 Erlenmeyer flasks; indicators and the acid solution for determining alkalinity. For determining acidity, very little additional equipment is needed. A very good set can be purchased, that will be suitable for all these tests, for probably less than $25. A pH test set should also be available.

Determining Alkalinity

The amount of alkalinity is determined by adding a standard acid in measured quantity; the acidity is determined by adding a standard alkali. The amount of acid or alkali required to neutralize the sample indicates the amount of alkalinity or acidity.

pH Determination.—The measurement of the intensity of alkalinity or acidity, that is, the hydrogen ion concentration or pH, is best performed by using an electrical pH indicator, but is satisfactorily made by using one of the several colorimetric pH comparators. With these, a small amount of the water to be tested is placed in a tube—from 5 to 15 ml.—and the color reagent is added. The color is then compared with glass or liquid standards. Thus pH determinations are extremely simple.



Courtesy Phipps & Bird

Stirrer for determining coagulant dosages.

The pH scale ranges from 1 to 14; 7 is neutral. Values below 7.0 indicate acid water; above 7.0 alkaline waters. The degree of intensity of acidity increases as the numbers become smaller: Thus 6.6 is acid, 5.8 more acid, 3.5 still more acid. The degree of intensity of alkalinity increases as the pH numbers increase: Thus 7.6 is alkaline, 8.5 more alkaline and 10.1 even more alkaline. In general, pH is determined to one decimal point, as 5.6, 7.4, 8.2 or 9.3.

This determination of the intensity of alkalinity does not give any indication of the *amount* of alkalinity that must be neutralized, except in conjunction with other tests.

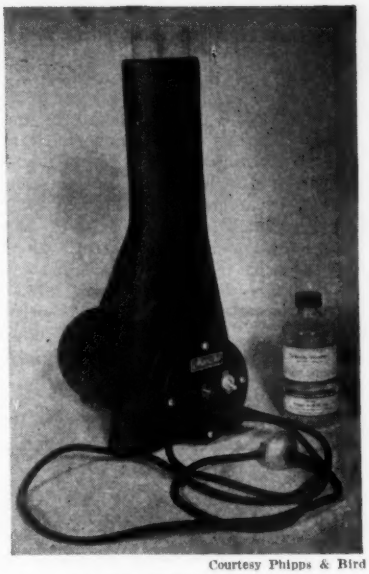
Amount of Alkalinity.—To test a sample for alkalinity by means of color indicators, 100 ml. of the sample is placed in an Erlenmeyer flask and four drops of the phenolphthalein indicator are added. Phenolphthalein alkalinity measures all of the hydroxides and half of the carbonates. The flask is shaken. If a pink or red color appears, the water is alkaline to phenolphthalein. If no color appears, the water contains no carbonate or hydroxide alkalinity. If there is a color, add the standard N/50 sulphuric acid solution drop by drop, shaking the flask after each addition, until the color just disappears. The number of ml. of acid solution used must be noted. The alkalinity to phenolphthalein is 10 times the number of ml. required to cause the color to disappear. If 3.7 ml. were required, the alkalinity to phenolphthalein is 37 ppm.

The sample already used for the phenolphthalein test is ordinarily used for the methyl orange alkalinity test; or a new sample of 100 ml. can be used. Methyl orange indicator is used to measure the total alkalinity. To the sample is added 2 drops of the methyl orange indicator. If the solution becomes yellow, there is hydroxide, normal carbonate or bicarbonate present. The N/50 solution of sulphuric acid is added, as before, until the yellow color just begins to turn to orange. The alkalinity to methyl orange in parts per million is equal to 10 times the number of ml. of sulphuric acid solution necessary to cause the color change. If a fresh sample has been used, and 5.8 ml. are required, the alkalinity to methyl orange is 58 ppm. Methyl orange alkalinity includes also the phenolphthalein alkalinity; hence if the sample previously used for phenolphthalein is used for the methyl orange test, the total amount of acid in both tests is used for computing.

If the water is turbid or colored, erythrosine should be used instead of methyl orange. Results are the same, but with this indicator the color change is shown by the drops of chloroform added, and not by the water. Details of this test are given in texts (1) and (2).

Types of Alkalinity

From the results of these tests, a great deal of information can be obtained regarding the mineral content of the water. But it is desirable first to mention the three types of alkalinity. These are bicarbonate alkalinity, which exists in the range below pH 8.3; the carbonate alkalinity with no CO_2 present which exists in the range above pH 8.3; and the caustic or hydroxide alkalinity, found above pH 9.4, and which may thus overlap the carbonate alkalinity.



Courtesy Phipps & Bird

The "St. Louis" turbidimeter.

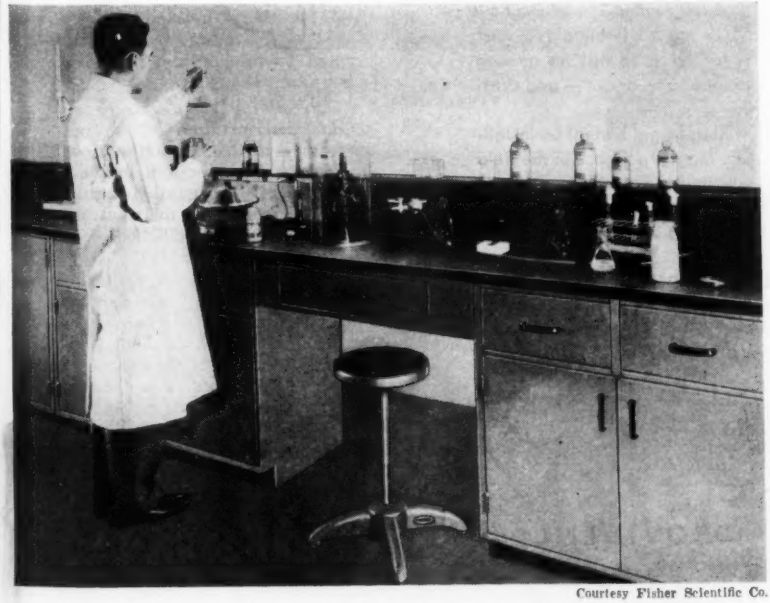
Determination of Types of Alkalinity.—(a) If the alkalinity to phenolphthalein is 0, that is, there is no color reaction to the addition of the phenolphthalein indicator solution, there is no caustic alkalinity and no carbonate alkalinity, but the alkalinity to methyl orange as shown by the test represents the bicarbonate alkalinity.

Example: Alkalinity to phenolphthalein is 0.0 ppm.; and to methyl orange is 18.5 ppm. Therefore, caustic alkalinity is 0; carbonate alkalinity is 0; and bicarbonate alkalinity is 18.5.

(b) When the alkalinity to phenolphthalein is less than one-half the alkalinity to methyl orange, there is no caustic alkalinity; the carbonate alkalinity is twice the phenolphthalein alkalinity; and the bicarbonate alkalinity is the methyl orange alkalinity minus twice the phenolphthalein alkalinity.

Example: Alkalinity to phenolphthalein is 28.0 ppm.; and to methyl orange 86.0 ppm. Therefore, caustic alkalinity is 0; carbonate alkalinity is 56.0 ppm.; and bicarbonate alkalinity is $86 - (2 \times 28) = 30.0$ ppm.

(c) When the phenolphthalein alkalinity is exactly one-half of the methyl orange alkalinity, the caustic alkalinity is 0, the carbonate alkalinity



Courtesy Fisher Scientific Co.

Laboratory furniture with gas, air and electrical conduits behind reagent shelves.

is the same as the methyl orange alkalinity, and the bicarbonate alkalinity is 0.

Example: Phenolphthalein alkalinity is 72.0 ppm. and methyl orange alkalinity is 144.0 ppm. Therefore, the caustic alkalinity is 0.0 ppm.; the carbonate alkalinity is 144.0 ppm.; and the bicarbonate alkalinity is 0.0 ppm.

(d) When the phenolphthalein alkalinity is more than one-half of the methyl orange alkalinity, caustic alkalinity is twice the phenolphthalein alkalinity minus the methyl orange alkalinity; the carbonate alkalinity is twice the difference between the phenolphthalein and methyl orange alkalinities; and the bicarbonate alkalinity is 0.

Example: The phenolphthalein alkalinity is 150 ppm.; the methyl orange alkalinity is 196 ppm. Therefore, the caustic alkalinity is $2 \times 150 - 196 = 104$ ppm.; the carbonate alkalinity is $2\ (196\text{-}150) = 92$ ppm.; bicarbonate alkalinity is 0.

(e) When the phenolphthalein and methyl alkalinities are the same, all the alkalinity is caustic alkalinity and carbonate and bicarbonate alkalinities are 0..

The alkalinity in natural waters is almost always bicarbonate alkalinity, though occasionally some carbonate is present in addition to the bicarbonate. Caustic alkalinity is found only in treated waters—most commonly in lime softened waters.

CO_2 Determination

To determine the free CO_2 content of the water, the same apparatus is required as for determining alkalinity; also the phenolphthalein indicator; and a solution of N/44 (or N/50) sodium hydroxide, which can be purchased ready for use.

To 100 ml. of the sample, 10 drops of the phenolphthalein indicator are added, and then the sodium hydroxide solution, drop by drop, shaking the sample meanwhile, until a faint pink color is produced. The free CO_2 in parts per million equals 10 times the number of ml. of the N/44 sodium hydroxide solution used. If an N/50 solution is used, the multiplier is 8.8.

The total acidity is obtained by adding 4 drops of the phenolphthalein indicator to 100 ml. of the water which has been placed in a white dish or in a flask on a white surface. The N/44 sodium hydroxide solution is then added until a pink color is obtained. The total acidity in parts per million of calcium carbonate equals 11.4 times the ml. of sodium hydroxide used. If an N/50 solution is used instead of the N/44, the multiplier is 10 instead of 11.4.

Acidity is reported as the parts per million of calcium carbonate.

Hardness

As already stated, calcium and magnesium compounds cause hardness. Formerly hardness was classified as temporary (which can be removed by boiling) and permanent (which cannot be removed by boiling). These classifications are best replaced by the terms carbonate and non-carbonate hardness.

Carbonate hardness is caused by the presence of calcium and magnesium bicarbonates. Non-carbonate hardness is caused by calcium and magnesium sulphates and chlorides.

Determining Hardness.—For an accurate determination of hardness it is necessary to determine the amounts of calcium and magnesium in the sample, which requires a lengthy chemical procedure. Training in this is available at various of the Short Schools conducted by many State Boards of Health. At least one device is on the market for measuring the hardness. For approximate measurement of the hardness, the soap test can be used, though what this actually measures is the soap destroying power of the water. The details of this test are given in texts (1) and (2).

Bacteriological Examinations

Bacteria are such very small organisms that a special unit of length is used to measure them. This is the micron which is .001 millimeter or about 1/25,000 inch long. One method of classifying bacteria is by shape. Under this method there are three general types:

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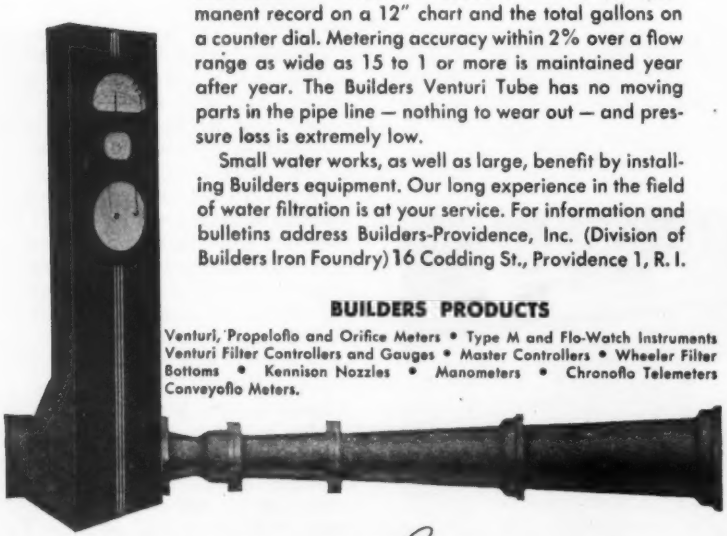

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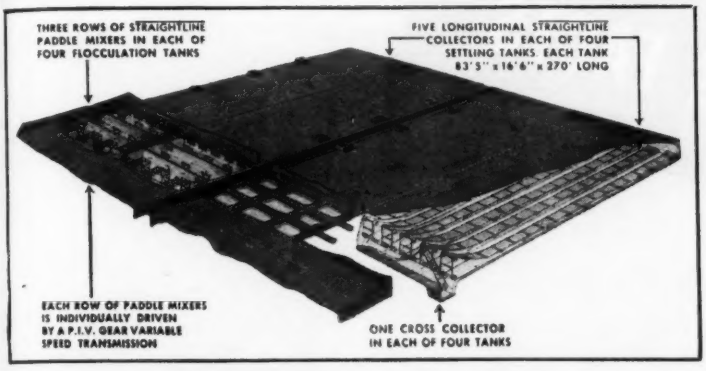
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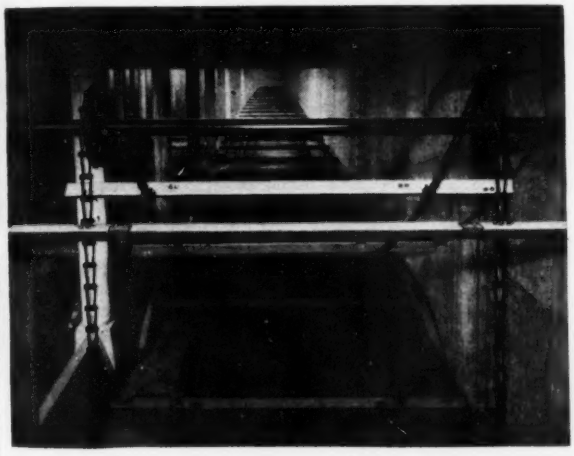

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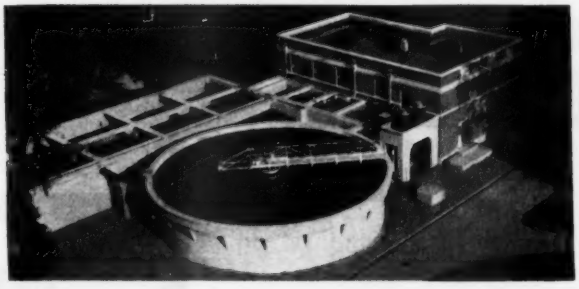

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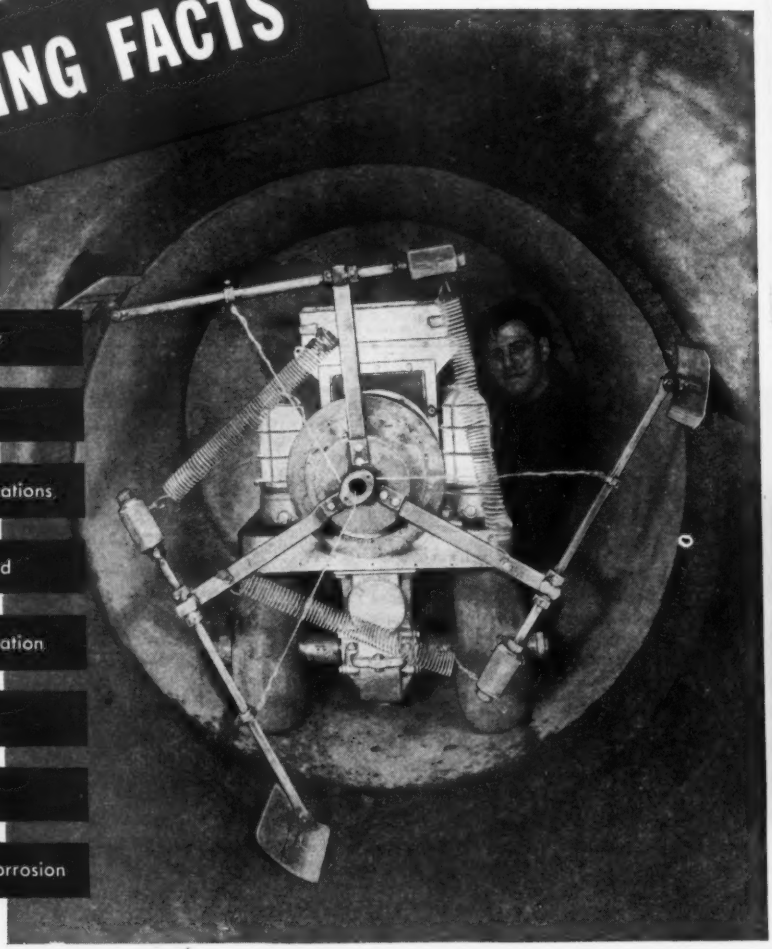

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Cocci, which are round or spherical; *Bacilli*, which are rod-shaped, like a cigar; and *Spirilla*, which are spiral, like a corkscrew. Bacteria normally found in water supplies are of the Bacilli group, and are from 1 to 4 microns long and about ¼ as thick. Because of their very small size, special methods are necessary in order to find and identify them.

For the water works operator or superintendent or sanitary engineer, concerned primarily with preventing waterborne disease, there are two broad classifications—*pathogenic*, which are disease-bearing or disease-producing; and *non-pathogenic*, which do not produce, cause or convey disease.

Non-pathogenic bacteria cannot be ignored entirely, because the presence of certain of these is often strongly indicative of the possibility that disease bearing bacteria also are present. For instance, typhoid bacteria (E. Typhosus) are very difficult to find in water, even when present, so that the usual method of procedure is to test for the coli-aerogenes group, which are constantly present in the human intestines and in urine and feces. If such bacilli are found it is practical proof that the water is contaminated with sewage. The coli-aerogenes group, however, do not cause disease.

It is for these reasons that reports of bacterial examinations of water show the results of tests for coli, and if these are present the water is condemned as bad, even though no examination has been made for B. typhosi or other pathogenic bacteria.

Bacteria multiply very rapidly so that a single bacterium, under favorable conditions, will produce many thousand others in the course of 24 hours. Temperature is important; for those organisms, such as coli and typhosi, which live in the body, body temperatures are most favorable, that is, around 98° F or 37° C, but multiplication takes place even at much lower temperature. A temperature of about 135° F kills most of these bacteria, but does not affect certain other forms of less importance to public health.

While low temperatures are unfavorable to bacteria, even freezing will not kill all of them, and typhoid bacteria have survived for months in ice. Therefore the use of ice from contaminated water is dangerous.

Collecting Samples

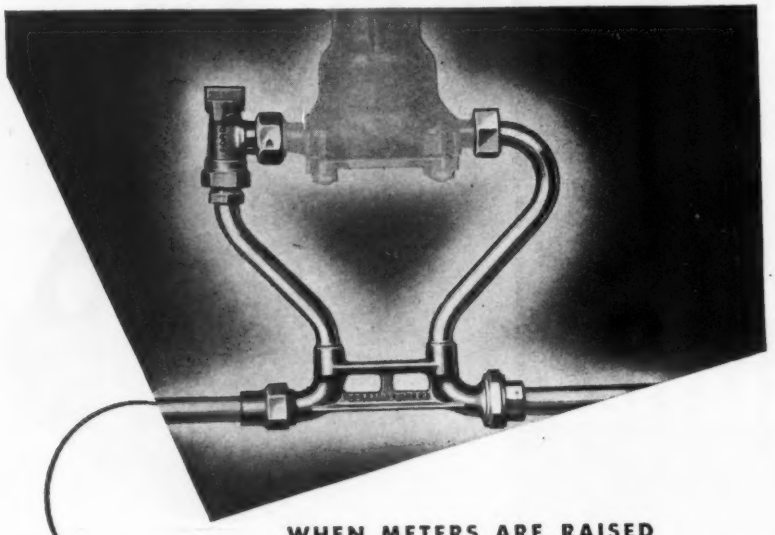
There are three important steps in examining water for bacteria: These are: (1) Collection of the sample; (2) determining the total number of bacteria; (3) determining the presence and total number of the coli-aerogenes group.

Samples must be collected in a clean, sterile, glass-stoppered bottle, from 4 to 8 ounces in capacity. Laboratories will furnish such bottles. Samples collected in other types of containers are valueless. When taking a sample from a faucet, the water should be allowed to run until water is drawn from the main. When drawing from a pump, or hydrant, the sample should be taken only after water from the main, well or reservoir is being drawn. In the case of a lake or stream the stopper is removed, the bottle placed beneath the surface and filled with a sweeping motion so water touching the hand will not enter the bottle.

Immediately after filling, the stopper is replaced, covered with tinfoil, paper or cloth and tied in place. Examinations should be made within 6 hours for impure waters and 12 hours for fairly pure waters. If examinations cannot be made within this period, the sample must be kept cold—between 40° F and 50° F. Even then changes may take place in the sample, such as multiplication of the bacteria.

The total number of bacteria is determined by mixing a small portion of the sample water with liquefied culture media and placing in a petri dish. This is then placed in an incubator for 24 hours, if the temperature is held at 37° C, or for 48 hours if the temperature is 20° C. Each bacterium in the water multiplies under those conditions into a colony which is visible without a microscope. Thus by counting the colonies on the culture media in the petri dish, the number of bacteria is known.

The examination for coliform bac-



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The above is but a brief outline of the procedures. These cannot be learned from any text. Attendance at Short Schools or other courses, or work in a laboratory is necessary before reliable results can be obtained.

Water Purification

Intakes and Screens

Intake structures are needed to draw water from lakes or streams; merely laying the pipe out into the water is not satisfactory, for the pipe may sink into the mud, or may draw sand or debris along with the water. The pipe must be protected from movement, and the intake be located somewhere near mid-depth of the water. This location avoids floating material, wave action, and surface ice; also stagnant water near the bottom.

Intakes vary greatly, according to the size of the water supply, depth and bottom character of the lake, direction and intensity of winds and currents, and quality of the water. Their design is an engineering job.

A screen should be placed over the pipe at the intake, or in the inlet structure of large intakes. Generally a screen having a mesh of about one inch may be used. The mouth of the pipe or the entrance to the pipe should generally be flared and the area of the screen openings should aggregate about twice the area of the pipe. A low entrance velocity draws less floating material into the inlet.

Screens at the intake should be removable, or other provision made for occasional cleaning. A rake can be used to remove any material caught on the screen. Occasional scrubbing and inspection is desirable.

Ice Troubles

In northern areas, anchor or frazil ice may cause troubles. Frazil ice consists of small crystals which are carried below the surface by even slight currents and which deposit on intakes or screens. Anchor ice forms directly on objects in shallow water. Metal surfaces are especially subject to ice clogging of this sort.

Occasional reversing of the flow of water from the pipe into the lake sometimes helps in removing ice accumulations. Large openings and low velocity through the intake reduce ice trouble. A boom of floating timber to create an area of still water around the intake is often helpful, especially in smaller reservoirs. Such a boom may also be advantageous in keeping leaves, twigs and other floating material away from the intake.

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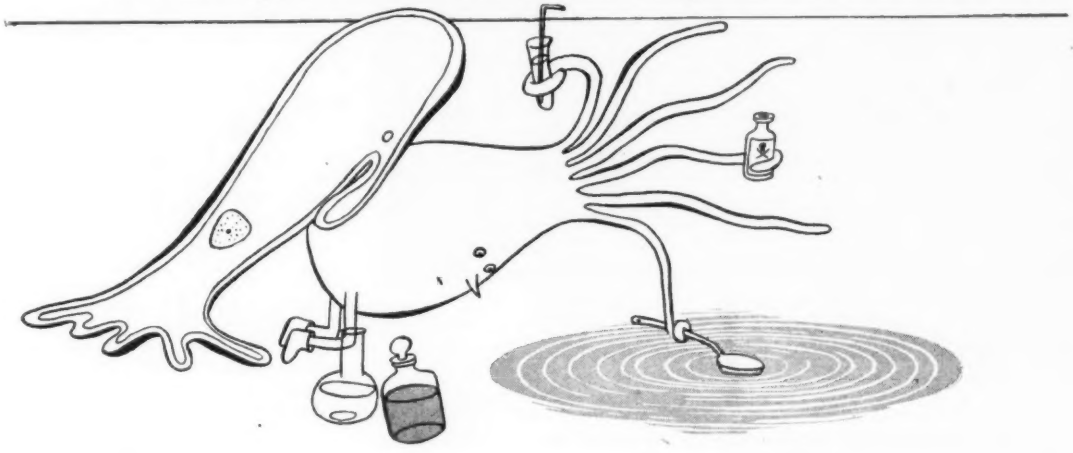

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Small oil or kerosene burning units to generate steam quickly are effective in removing or in relieving frazil or anchor ice clogging. A very small rise in temperature on the exposed surfaces is enough to free them from the ice.

There are several types of screens that can be installed at or near intakes that clean themselves automatically. These consist of an endless or jointed belt of screens which are moved slowly upwards by a small motor. The solids caught on the screen are removed at the top by a small jet of water and dropped into a trough.

This type of screen can be installed at an intake, if electric power is available, or at the treatment plant or reservoir. A ¼ or ⅛-inch mesh screen is commonly used, this being possible because regular cleaning prevents clogging. Occasionally a finer screen is used .Denver has used a 60-mesh screen, primarily to remove algae and slimes.

Screens should be in duplicate, if of the fixed type; or the moving type described just previously can be used. Double screens are often used.

Fixed screens should be scrubbed or squeegeed as necessary to keep them clean; debris collected in them should be removed. If possible to do so, the flow of water through them should be reversed or the water shut off and the wash water wasted. Revolving screens may be hosed down or scrubbed from time to time; lubrication on mechanical screens should follow the directions of the manufacturer.

Sedimentation and Settling

Sedimentation consists in holding the water in, or passing it very slowly through, reservoirs, tanks, or basins. The particles of sand or clay that cause turbidity are about 2.65 times as heavy as an equal volume of water. If the water is held quiescent or practically so, much of this turbidity will settle to the bottom, but currents or eddies tend to hold the smaller particles in suspension and prevent them from settling. Sedimentation basins may be any size—from those that hold the water for only 2 to 4 hours, up to large reservoirs, where the water is stored for weeks or even months.

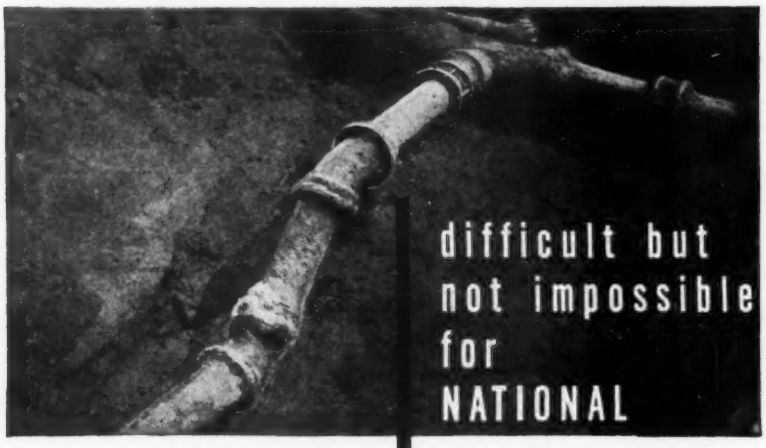
In sections of the country where clay soils predominate, sedimentation alone will not remove the turbidity. Chemicals are then added—usually aluminum sulphate (commonly but erroneously called alum) or ferrous or ferric sulphate and lime. These chemicals produce an insoluble flocculent precipitate, called "floc," which settles quite rapidly, carrying with it the very fine particles of clay, and producing a clear water. After such treatment, the water must be filtered to remove the small particles of floc which do not wholly settle out.

Sedimentation without chemicals is called "plain sedimentation"; when chemicals are used to produce a floc and this is afterwards allowed to settle, the process is called "coagulation and settling." These are the two types of sedimentation; they will be considered separately later.

Plain Sedimentation Basins

There is relatively little that the operator can do to improve the operation of plain sedimentation basins, other than to see that the inlets and outlets are kept clean, and that sediment is removed at proper intervals. Modification of inlets and outlets, and installation of baffles should be made only after careful study. The purpose of the inlet is to permit the entrance of the water into the basin with the least possible disturbance or agitation; and of the outlet to allow the water to flow out of the basin without creating undesirable currents or eddies. Baffles or partitions may be of value in creating an even flow through the tank, and to prevent any tendency toward "short circuiting" or direct flow from inlet to outlet. If these structures do not operate properly, careful consideration should be given to any contemplated changes before they are made.

Cleaning Settling Basins.—Most plain sedimentation basins do not have any provision for quick and easy removal of the sediment that accumulates in them. At intervals—usually when the depth of sediment has reached 3 or 4 feet—the basins must be emptied of water and the sand and mud flushed out or removed with scrapers or other tools.



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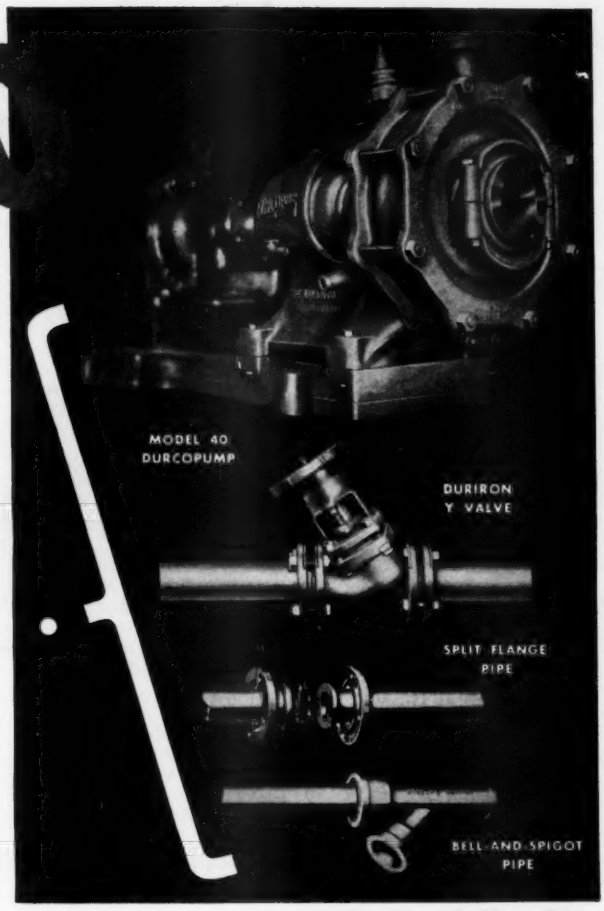

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Application	*Corrosive*	*Material and Equipment*
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	Copperas "sugar" sulfate	Duriron pipe and fittings.
	Alum (all types)	Duriron pumps, valves, pipe and fittings, special castings
Disinfecting	Chlorinated water, sodium or calcium hypochlorite, etc.	Durichlor (or Duriron) pumps, valves, pipe and fittings, hose connections, special castings.
Taste and Odor Control	Activated Carbon	Duriron pumps, valves, pipe and fittings.
Algae Control	Chlorinating Compounds	Durichlor pumps, valves, pipe and fittings.
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Chemical Coagulation

Coagulation is a preliminary step to prepare the water for filtration. It is not a complete treatment process. Nevertheless, proper preparation of the water, or "conditioning" prior to filtration is one of the most important steps in water purification. Study, research and care in this stage of treatment will pay large returns in reduction of filter troubles and in the quality of the water delivered to the consumers.

In coagulation, aluminum sulphate or other suitable chemicals are added to the water. These react with materials present in the water (or with each other) and after a short time a flocculent and gelatinous precipitate forms. This attracts or envelops the finely divided particles of clay, silt and organic matter, forming particles of floc varying in size from those barely visible to feathery flakes. These floc particles settle quite rapidly and completely, leaving a relatively clear water.

Factors Affecting Chemicals. — (a) The dosages of chemical required may vary with the amount and kind of turbidity present, with the alkalinity or acidity of the water with its pH value, with the temperature, and with other factors. Thorough mixing of the chemical with the water, and an adequate period of reaction and of settling are necessary for economy and good results.

(b) *Effects of Temperature.*—While the results vary with different chemicals, it is generally the case that slightly more coagulant is required at temperatures below 35° F to 40° F and above 65° F to 70° F. Chemical reactions are always slower and less complete at low temperatures, while at the higher temperatures there is sometimes a reabsorption of the floc.

(c) *Effect of Alkalinity, Acidity and pH.*—The effect of these factors depends upon the type of coagulant used. Each one has its reaction range within which it performs most successfully.

Aluminum Sulphate

Aluminum sulphate, usually called filter alum, and the chemical most commonly used in coagulation has the theoretical formula $Al_2(SO_4)_3$, 18 H_2O. In order to form a floc, alkaline carbonates (calcium, sodium or magnesium carbonates) must be present in the water, and if these are not present, lime or soda ash must be added to supply the necessary alkalinity.

When calcium bicarbonate is present in the water, and almuninum sulphate is added, as follows:

$$\underset{\text{aluminum sulphate}}{Al_2(SO_4)_3} + \underset{\text{calcium bicarbonate}}{3\,Ca(HCO_3)_2}$$

the chemicals present combine to form the following compounds:

$$\underset{\text{calcium sulphate}}{3\,Ca\,SO_4} + \underset{\text{aluminum hydroxide}}{2\,Al\,(OH)_3} + \underset{\text{carbon dioxide}}{6\,CO_2}$$

The aluminum hydroxide is the desired floc. It should be noted that a moderate excess of calcium bicarbonate does not interfere with the reaction; it is not necessary to add enough aluminum sulphate to combine with it all. Only enough of the $Al_2(SO_4)_3$ is necessary to produce a floc satisfactory in volume and size of particles.

If sodium carbonate is used, instead of calcium bicarbonate, and aluminum sulphate is added, as follows:

$$\underset{\text{aluminum sulphate}}{Al_2(SO_4)_3} + \underset{\text{sodium carbonate}}{3\,Na_2CO_3} + \underset{\text{water}}{3\,H_2O}$$

The following compounds are produced:

$$\underset{\text{sodium sulphate}}{3\,Na_2(SO_4)_3} + \underset{\text{aluminum hydroxide}}{2\,Al(OH)_3} + \underset{\text{carbon dioxide}}{3\,CO_2}$$

The complete reaction, when aluminum sulphate is used, requires theoretically 7.7 ppm. of alkalinity for each gpg (17.1 ppm.) of alum; but in actual practice each gpg. of alum requires 6 to 10 ppm. of alkalinity with which to react, and there should be also an excess alkalinity of 20 to 25 ppm. in the filtered water in order to prevent corrosion.

For instance, assuming that 8 ppm.

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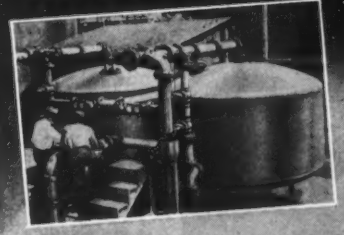

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of alkalinity is required for each gpg. of aluminum sulphate used, with a dosage of $Al_2(SO_4)_3$ of 1½ gpg., there will be required 8 x 1½ = 12 ppm. of alkalinity for the reaction with this amount of aluminum sulphate. There will also be required an alkalinity of 25 ppm. to prevent corrosion. Therefore a total of 37 ppm. of alkalinity will be required. If this is not present, it must be added in the form of lime or soda ash.

If there is not enough alkalinity to react, as above, some of the aluminum sulphate will remain in solution. If there is no reserve of alkalinity after the reaction, the water will be corrosive, due to the CO_2 released by the reaction, with the aluminum sulphate. Lime (CaO), hydrated lime ($Ca(OH)_2$), or soda ash (sodium carbonate, Na_2CO_3) can be used to furnish alkalinity; 0.5 grain of sodium carbonate combines with 1 grain of aluminum sulphate, and in doing so produces 3.4 ppm. of free CO_2; 0.5 grain of sodium carbonate will combine with 3.6 ppm. of CO_2. Therefore 1 gpg. of sodium carbonate reacts with 1 gpg. of aluminum sulphate, furnishing the required alkalinity and combining with the free CO_2 produced. When lime is used, 1 gpg. of aluminum sulphate will combine with 0.35 gpg. of lime, and the CO_2 produced by the reaction is neutralized by about 0.35 gpg. of lime.

Aluminum sulphate reacts best at pH values of 5.5 to 8.5. A minimum dosage in clear water is about 0.3 gpg. Larger amounts are required for turbid waters, but there is no fixed rule to govern dosages. Experiments and experience with each water form the best guide. Large flakes of floc generally indicate a dose larger than is needed.

Iron Salts

Ferric sulphate ($Fe_2(SO_4)_3$), is also widely used in coagulation, principally in the granular form in which it is known by such trade names as Ferrifloc. It is a free-flowing chemical that can be fed dry. In general, ferric sulphate behaves much as does aluminum sulphate, but it will produce a satisfactory floc over a somewhat wider pH range. It has advantages where manganese is present in sufficient quantity to require removal. The reactions, when using ferric sulphate are as follows:

$$\underset{\text{ferric sulphate}}{Fe_2(SO_4)_3} + \underset{\text{hydrated lime}}{3\,Ca(OH)_2}$$

combine to form

$$\underset{\text{calcium sulphate}}{3\,Ca(SO_4)} + \underset{\text{ferric hydroxide}}{2\,Fe(OH)_3}$$

The ferric hydroxide is the desired floc.

Ferrous Sulphate, frequently called copperas, should not be confused with copper sulphate which is used for algae control. It has the formula $FeSO_4$, $7\,H_2O$. It is available in lump form, or as the granular sugar sulphate of iron, in which form it contains less than 7 molecules of water.

Chlorinated copperas is made at the point of use by adding chlorine to a ferrous sulphate solution. It is effective in removing color, as the hydroxide forming the floc is insoluble, even over a wide pH range. Coagulation and floc formation are usually best at a pH below 7, especially where color removal is a principal object of treatment.

Other Chemicals

Lime is available as calcium oxide, CaO or hydrated, $Ca(OH)_2$. The calcium oxide is the quicklime and must be slaked before use, and fed as a suspension. Hydrated lime can be fed dry. When used in large quantities, as in a large plant, the quicklime is cheaper, but hydrated lime is handier for the small plant. It does not deteriorate when stored in a dry place and is obtainable in handy-sized paper bags.

When using lime, the calcium content is important, and must be known in order to dose properly. Quicklime may vary from 75% to 99% CaO, and should be bought and used on the basis of its CaO content. Hydrated lime varies between 85% and 99% $Ca(OH)_2$.

Assuming 100% CaO in the quicklime and 100% $Ca(OH)_2$ in the hydrated lime, 75.7 pounds of quicklime equals 100 pounds of hydrated lime; and 100 pounds of quicklime is equal to 132 pounds of hydrated lime. These relationships must be modified by the contained percentage of CaO or $Ca(OH)_2$ in the lime used. For instance, if the hydrated lime contains 95% $Ca(OH)_2$, it will require $132 \div 95 = 140$ pounds to equal 100 pounds of 100% CaO.

Lime is used in coagulation to provide added or "artificial" alkalinity for reactions with aluminum sulphate and copperas, and also for softening. It may be used alone as a coagulant for waters containing a large amount of magnesium, by the precipitation of magnesium hydroxide by excess lime.

Soda Ash is the common name for sodium carbonate, which has the formula Na_2CO_3. It is used, as already stated, to furnish artificial alkalinity for coagulation, and also for softening water. Most soda ash is 98% or more sodium carbonate. Though soda ash is more costly than lime, it has advantages for coagulation in the small plant. It is easy to feed, eliminates "after precipitation" and does not increase hardness.

Sulphuric Acid, H_2SO_4, is sometimes used in water purification principally to reduce the pH of certain colored waters. Most colored waters coagulate best when slightly acid, and the lower pH may also reduce the amount of aluminum sulphate required for coagulation.

Silicate of Soda has been found to have, under certain conditions, the property of improving the formation of alum floc particles, and causing more rapid and complete sedimentation and a clearer effluent.

A more complete and elementary discussion of chemical reactions is available in Water and Sewage Chemicals and Chemistry, Text (3).

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How to Compute Chemical Dosages

There is no formula for determining coagulant doses for best clarification. Acidity, alkalinity, the character and amount of turbidity, temperature, color and other factors influence the amount and even the type of chemical. Results obtained in another plant, even one treating water of a similar nature, can be used only as a rough guide. Laboratory tests are valuable indicators of the probable dosages that will be required and should be used frequently; but, in the final analysis, actual records of results at the plant in question are the best guide.

Procedure in Making Tests.—In making tests, a measured amount of the water to be coagulated is placed in beakers or jars, and dosed with different amounts of coagulant. The water and coagulant is then stirred until the floc forms, and this is allowed to settle, duplicating as closely as possible plant operations.

There are available several excellent devices consisting of 1, 2, 4 or 6 beakers, each holding about 1 liter, with electrically driven paddles for stirring the water to form the floc. Some of them have arrangements for varying the speeds of the paddles. Equipment with 4 or 6 jars is preferable. If such equipment is not available, quart fruit jars may be used, and the stirring done by hand, with a glass rod or an eggbeater. It is best to mark each jar or beaker to indicate exactly one liter; or 1 quart, if this unit of measure is to be used.

Preparing the Solutions

It is best to use the chemicals at hand in the plant. No allowance for strength or purity need be made in this case.

Coagulants.—While the use of grains per gallon is most common in plant practice, the use of parts per million is preferable for making laboratory tests, especially since the two terms are easily converted. Add 10.0 grams of aluminum sulphate, ferric sulphate, or other coagulant to 1 liter of distilled water. One ml. of this solution, when added to 1 liter of the water to be treated is equal to a dose of 10 ppm. or 0.58 gpg.

Lime and Soda Ash.—Add 10.0 grams of soda ash or lime to 1 liter of distilled water. One ml. of this solution when added to 1 liter of water is equal to a dose of 10 ppm.

Dosages in Grains per Gallon.—To prepare a solution for dosages in grains per gallon, add 17.1 grams of the chemical to 1 liter of distilled water. One ml. of this solution when added to 1 liter of the water to be treated equals a dosage of 1 grain per gallon.

Dosages on Quart Basis.—To prepare a solution for dosages for quart jars, add 8.95 grams of the chemical to 1 quart of water. One ml. of this solution, added to 1 quart of water gives a dose of 10 ppm.

Chemical Dosages for Alkaline Water

Waters that have 40 or more ppm. of alkalinity will normally react to aluminum sulphate without the addition of lime or soda ash. Assuming the water contains sufficient alkalinity, that the test is being made with 6 jars, and that the solution being used contains 10 grams of aluminum sulphate to 1 liter of water, the jars may be dosed as follows:

Jar. No.	*Dose in ml.*	*in ppm.*	*in g.p.g.*
1	1	10	0.58
2	2	20	1.17
3	3	30	1.85
4	4	40	2.34
5	5	50	2.92
6	6	60	3.50

After stirring for about 15 minutes, allow the samples to stand and note the floc that forms. If none forms, the water is probably deficient in alkalinity or has other characteristics that require even more coagulant. The smallest dosage of chemical that produces a good floc that settles well should be used. A large flaky floc indicates that the dose of chemical may be reduced. Note the

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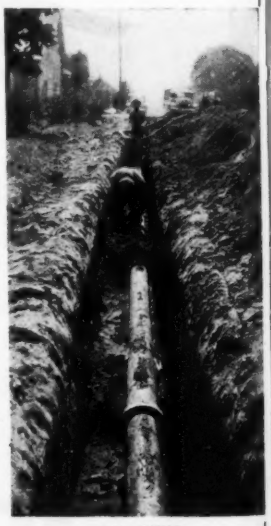

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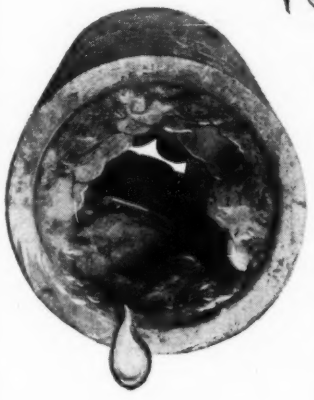

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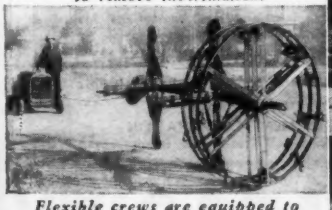

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pH of the water in the jar showing the most satisfactory floc.

Water Deficient in Alkalinity

When using aluminum sulphate, 1 gpg. requires 7.7 ppm. of alkalinity, and there should be also an excess of 20 to 25 ppm. of alkalinity to prevent corrosion. If the alkalinity of the water is known, the requirements for coagulation can be computed approximately, and the deficiency in alkalinity determined.

Assuming that the natural alkalinity of the water to be treated is 22; that each grain per gallon of aluminum sulphate requires 8 ppm. of alkalinity (instead of the theoretical 7.7 ppm.); and that an excess alkalinity of 25 ppm. is desired, the amount of lime or soda ash that must be added for any dosage of aluminum sulphate is computed as follows:

		Alkalinity, ppm.			
Coagulant g.p.g	*Reaction*	*Reserve*	*Total*	*Natural*	*Added*
1	8	25	33	22	11
1½	12	25	37	22	15
2	16	25	41	22	19
2½	20	25	45	22	23
3	24	25	49	22	27
3½	28	25	53	22	31

The same procedure is then followed as for the use of aluminum sulphate in alkaline waters, except that soda ash or lime solution, prepared as already described, is first added to each jar to give the dosage shown in the last column of the above table, that is, 1.1-ml. for jar No. 1; 1.5 ml. for jar No. 2, etc.

Results given by such tests are valuable as a guide in finding what dosage is best on a plant scale. The dosage shown as best by the jar test may not be the best one, in actual plant practice, but it will usually be close to it, and with some modifications will usually give excellent results.

Example.—From the jar test, it is found that 1½ gpg. of aluminum sulphate and 15 ppm. of added alkalinity give best results. The flow of water to be treated amounts to 720,000 g.p.d. How much chemical is needed?

Solution.—A dosage of 1½ gpg. equals 142 x 1½ = 213 pounds per million gallons. The flow is .72 mgd. Thus the aluminum sulphate required is .72 x 213 = 153.4 pounds per day. There must be added 15 ppm. of soda ash or its equivalent. The amount required is 15 x 8 1/3 x .72 = 90 pounds per day of soda ash.

Filters and Their Operation

For filter purposes, quartz sand or silicates (sometimes also anthracite coal), which are not affected by the water, should be used. Ordinary bank sand cannot be used without screening, washing and grading to produce the correct size, and unless it is free from lime and magnesium carbonates.

If the sand is too fine, it will offer excessive resistance to the passage of the water and will require frequent cleaning; if too coarse, it may remove too little of the material that it is desired to take out. From experience over a long period of years, the sizes of sand that give best results have been determined. Two important factors, aside from those of the composition of the sand are "effective size" and "uniformity coefficient."

Effective Size of Sand.—The *effective size* of a sand is that size such that 10% of the sand grains by weight are smaller than it. This factor is simply a means of describing the fineness of a sand in terms that can be used with precison and exactness in water works practice. When described by this term, a fine sand would be one having an effective size of 0.17 or 0.18 millimeters; and a coarse sand would be one having an effective size of 0.45 or 0.50 mm.

Uniformity of Sand.—The uniformity of a sand is another characteristic of importance in water purification.

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The *uniformity coefficient* is the ratio between the effective size and that size such that 60% of the sand is finer than it. Both uniformity and effective size are necessary to describe a sand.

Mechanical or Rapid Sand Filters

A rapid sand filter consists of a bed of sand about 24 to 30 inches deep which is supported on a layer of graded gravel 12 to 18 inches deep. The sand usually used in a filter of this type should have an effective size of 0.35 to 0.50 mm., and a uniformity coefficient of 2.0 or less; that is, the sand should be quite uniform in size. The gravel ranges from 2-inch or 3-inch pieces at the bottom to coarse sand at the top.

The rapid sand filter operates at a rate of about 125,000,000 gallons per acre per day, or 2 gallons per square foot per minute. Because of this rapid rate, and the volume of water filtered special provisions for frequent and rapid washing are necessary.

This is accomplished by reversing the flow of water through the filter, and by passing it upward through the sand at a rapid rate. This washes dirt out of the sand; the dirty water flows off into wash water troughs or gutters and is wasted.

Before filtration, the water is always conditioned by coagulation and settling, as previously described. This also is important in insuring good filtration and a clear water. Particles of the floc which do not settle collect on the surface of the sand and form a mat which aids in straining all the suspended matter and most of the bacteria from the water.

A filter unit 18 ft. by 20 ft. will handle about 1 mgd. Units vary from ½ mgd., or even less, to 2 mgd. or more in the larger plants. In very small plants, the units may be circular.

Loss of Head. — The gravel bed depth (12 inches or more), plus the depth of sand bed (usually 30 inches), plus the height of the wash water troughs above the sand (usually 24 inches), plus the freeboard above the troughs (usually some 4 feet) make up the depth of the filter. On the above basis, the depth would be 9 feet 6 inches, which would be the head available without employing negative head or suction.

When the filter is first put in operation after washing, the loss of head due to friction in passing through the sand is small—perhaps a foot. As the filter becomes dirty, this increases; when it becomes as much as 7 to 9 feet, the filter must be washed. This variation in loss of head requires the use of rate controllers so that a uniform rate of filtration is maintained at all times.

Rate Controllers—A rate controller is designed to regulate automatically the flow through the filter so as to maintain a uniform rate of discharge regardless of the amount of loss of head in the sand, or of the change of elevations of the water in the filter and in the clear water basin. It does this by adjusting the valve openings as necessary so that a pre-determined or "set" flow shall pass through them from the start of the filter run until the valves are wide open. It is a mechanical hand which controls the valve during the entire run of the filter. For best results a rate of not more than 2 gals. per sq. ft. per minute should be maintained.

Checking Rate of Flow Through Filters.—Operators can calculate the rate of flow through the filter, thereby checking the rate controller, as follows: Fill the filter with water; shut off the influent line; determine the time necessary to filter down one foot. For example, if it requires 4 minutes for the water to drop one foot, the rate of filtration is $7.48 \div 4 = 1.87$ gals. per square foot per min. This multiplied by the filter area will give the rate in gallons per minute for the entire filter unit; and this result multiplied by 1440 will give gallons per day.

Washing Filters

When the loss of head in the filter has reached the point where washing is necessary, the influent valve is closed, and the water is drawn down below the tops of the wash water troughs, the filtered water outlet being closed. Water is then admitted slowly to the underdrain system, and then more rapidly until the usual washing rate is attained.

In most plants this rate is 15 gallons per square foot per minute, or about

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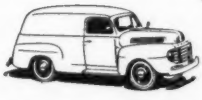
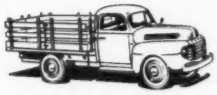
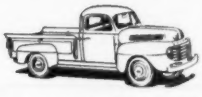


F-1—4,700 lbs. GVW. 8′ Panel, 6½′ Pickup, 6½′ Platform or Stake. 114″ w.b. V-8 or Six.

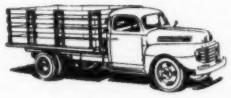


F-2—5,700 lbs. GVW. 7½′ Platform or Stake, 8′ Express. 122″ w.b. V-8 or Six engine.

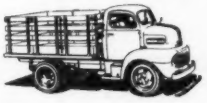


F-3—6,800 lbs. GVW. 7½′ Platform or Stake, 8′ Express. 122″ w.b. V-8 or Six engine.

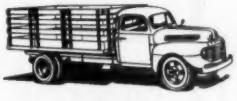
F-4—7,500 lbs. GVW. (singles), 10,000 lbs. (duals). 9′ Platform or Stake. 134″ w.b. V-8 or 6.



F-5—14,000 lbs. GVW. 9′ & 12′ Platforms or Stakes. 134″ w.b. & 158″ w.b. V-8 or Six engine.



F-5 C.O.E.—14,000 lbs. GVW. 9′ & 12′ Platforms or Stakes. 110″-134″-158″ w.b. V-8 or Six.



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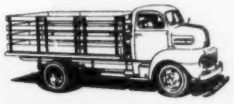

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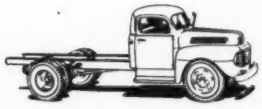
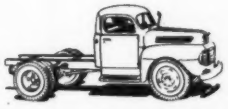


F-7—19,000 lbs. GVW. 135″-159″-195″ w.b. 9.00-20 maximum tires. 145 h.p. V-8 engine.



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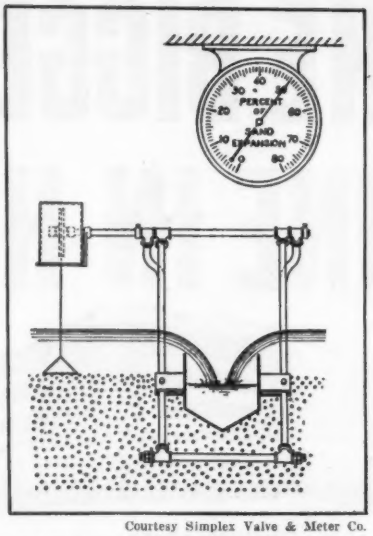
7½ times as fast as the filter rate. Also since there are 7½ gallons in a cubic foot, the rate is 2 cu. ft. of water per square foot and the "rise" or upward velocity of the water is 24 inches per minute. On some of the newer plants, higher rates are used (as high as 36 gpm. per square foot). By timing the rise of wash water in the filter, the rate of wash can be determined. For instance, if the water rises 2 ft. in one minute, the washing rate is 2 x 7.48, or about 15 gals. per sq. ft. per min.

The upward flow of water "floats" the sand, expanding it by 40% to 50% of its volume, and washes out the dirt; the dirty water overflows into the wash water troughs and out through the waste drain. Washing should continue until there are large clear areas in the wash water as it rises through the filter. Washing will ordinarily take 7 to 10 minutes. When it is completed, the wash water valve is closed; the waste or sewer valve is closed, and the influent valve is opened sufficiently to bring the water in the filter to its normal level. The water is then allowed to filter to waste for at least 3 to 5 minutes in order to build up a mat on the surface of the sand sufficient to produce a clear effluent. Bacterial removal is not good immediately after washing.

Air Wash.—Some filters have small pipes between the sand and gravel layers, which pipes are for the purpose of carrying air under pressure to agitate the sand. This air is furnished from a compressed air tank or from a compressor unit. In washing, the influent valve is closed and water drawn down nearly to the surface of the sand. The air is then applied at the rate of 2 to 5 cu. ft. of air per square foot of filter per minute for 3 or 4 minutes. After the agitation and stirring have been accomplished, the air valve is closed, filtered water turned into the underdrains, and washing carried on as before described. Less wash water is used—generally 6 to 10 gallons per square foot per minute.



Courtesy Simplex Valve & Meter Co.

A handy sand expansion measuring device.

Surface Washers.—There are several types of surface washers, among which are the Palmer revolving and the Baylis, which is stationary. Both wash the sand through agitation by jets of water. This type of washer may reduce wash water use, frequency of washing and operating difficulties.

Measuring Sand Expansion. — The upward velocity of wash water should be sufficient to expand the sand from 40% to 50%; that is, with a sand bed 24 inches deep, the depth during washing should be 33 to 36 inches. During the summer, there may be less sand expansion; even not enough to insure proper washing at the 15 gpm. rate. This is due to the higher temperature and consequent lower viscosity of the wash water, and it may be necessary to increase the wash water rate.

To measure the expansion of the sand, a sand expansion indicator may be used. Efficient indicators may be purchased. Samples from the wash water trough, if placed in bottles and allowed to settle, will show if sand is being lost in washing. The loss of the finest sand from a new filter may be expected at first and is not objectionable.

Filter Operating Difficulties and Their Correction

Mud Balls.—Mud balls may form in or on the sand. These generally indicate that the water applied to the filter has been imperfectly treated; or the velocity of the wash water is too low; or the time of washing too short; or the wash water is improperly distributed; or sometimes that the rate of operation is excessive. Mud balls may be removed by scraping the sand with shovels; or sometimes during washing by skimming them off with a long handled basket of ¼ inch wire mesh. On relatively small beds, the sand may be raked during the washing process by long-handled rakes, which break up the balls. Prevention is desirable. Proper pretreatment of the water is most effective.

Mud Layers.—The presence of mud evenly distributed over the bed after washing, or accumulations of it near the wash water troughs indicate that wash water velocity is too low, washing time too short, troughs too high, or troughs too far apart.

Cracks.—Cracks in the sand are usually due to mud being carried into the sand because of insufficient washing; but also may be due to the presence of clay or other cementing material which binds the sand grains together. A hand rake may be used to break up such areas. Proper pretreatment of the water will reduce trouble from cracks.

Clogging.—When mud balls merge or coalesce, large areas of compacted mud may form. This results in uneven loading and operation of the filter, shortened filter runs, and often a poorly filtered water. Adequate pretreatment will reduce or eliminate the cause of such trouble. Deposits can be broken up with water jets; where applicable, chemicals can be used; or the sand may be washed.

Calcium Carbonate Coating.—When the water contains an excess of calcium carbonate, this may be deposited on the sand grains, which are thus enlarged. Proper treatment of the water is necessary for prevention. For curative treatment, samples of the sand should be tested in the laboratory to determine whether hydrochloric or carbonic acid is the more effective in dissolving the coating, and the amount required. A 2% solution, by weight, of sulphur dioxide is often used, sufficient in vol-

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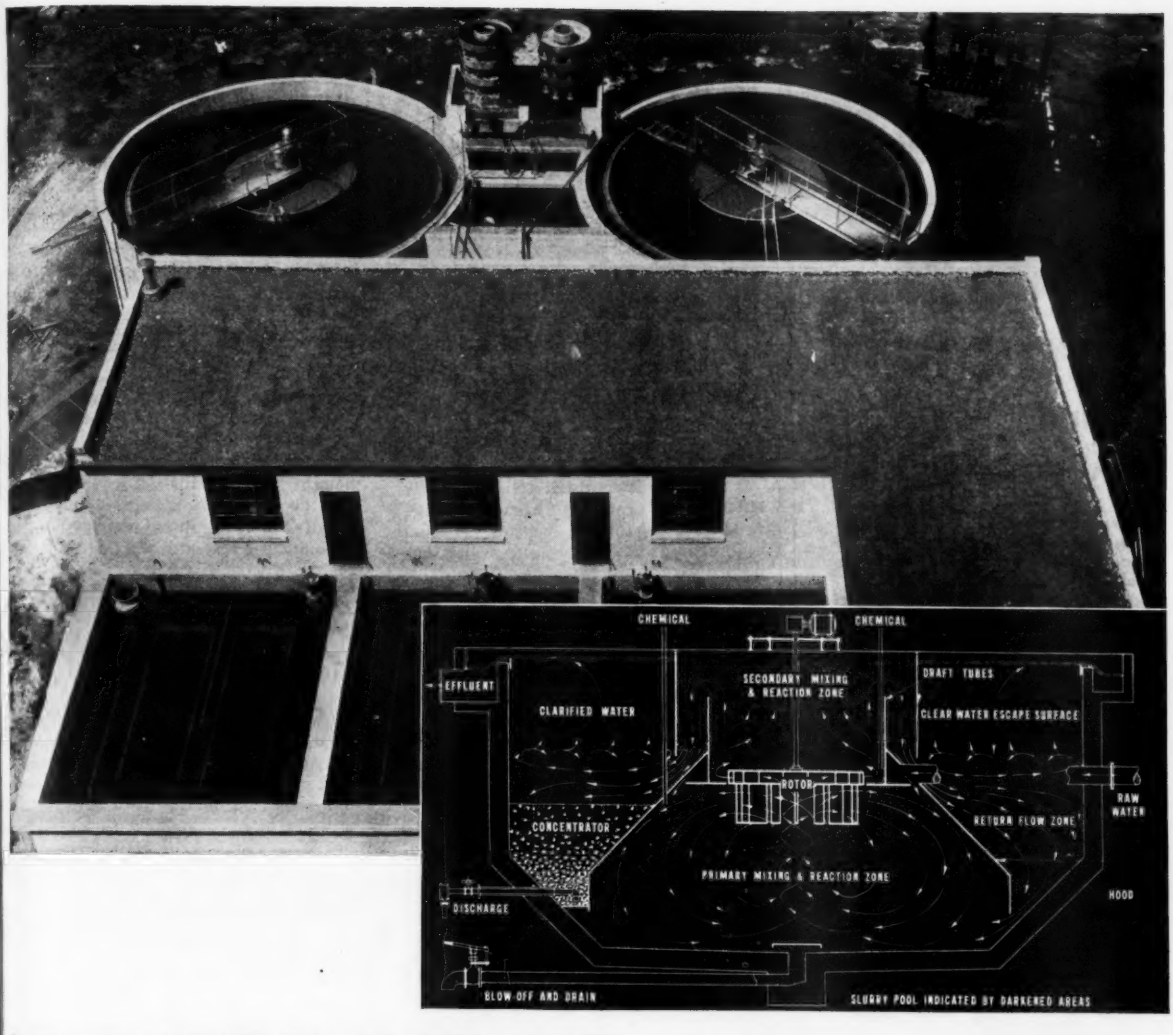

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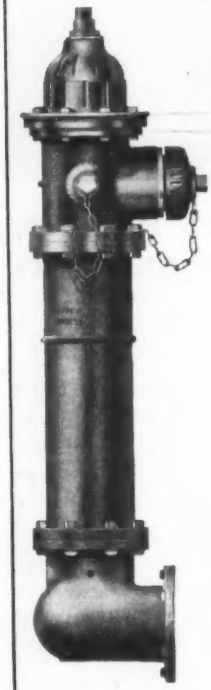

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ume to fill (and cover) the sand bed.

Breaks in the underdrain system or in the gravel layer may result in concentration of wash water into a channel, with mounds of sand forming. Removal of the sand and repair are required.

Shrinkage of sand beds is sometimes due to the cementation of the sand grains by organic matter or gelatinous floc; also at times by fine clay, oil or microorganisms. Most of these can be remedied by treatment with alkali. A 2% or 3% solution by weight of caustic soda, sufficient in volume to fill the bed and cover the sand to a depth of 3 or 4 inches is used. This, if allowed to stand 12 to 24 hours, will usually prove helpful. The outlets of the filter unit should, of course, be closed before the caustic soda is added: after the washing solution is drained off, the bed must be washed thoroughly.

Chlorine also is used. It is especially effective for destroying algae or slime-producing organisms. A strong solution is prepared, and after the water has been drawn down to about a foot above the top of the sand, this water is dosed to give a strength of about 3,000 ppm. The treated water is then lowered to about an inch above the sand level, thus drawing the chlorinated water into the interstices of the sand; after about 24 hours of contact, the bed is washed thoroughly. Another method is to add chlorine to the wash water and backwash until there is at least 10 ppm. of chlorine in the water at the top of the bed. This chlorine solution is allowed to stand for 24 hours, after which the bed is washed thoroughly.

Inspection.—From time to time after washing a filter the water should be drawn down below the surface of sand to permit inspection and examination.

Removing Sand. — Removal of the sand and gravel from the bed is a major operation, and is rarely necessary. Broken or clogged strainers occurring in sufficient number may make sand removal necessary for repair and replacement, but as long as satisfactory bacterial removal and turbidity reduction are obtained the presence of a few defective strainers is not important.

Washing.—Filters are washed whenever the loss of head or decrease in efficiency indicates. There is no set rule for this; as a matter of fact, the filter units in a given plant may vary somewhat; and there will also be variations from month to month, or even oftener.

There is no substitute for intelligent observation, the keeping of proper records, and a thorough knowledge of conditions at the plant. These form the best basis for good operation. Also there is a large amount of written and recorded experience covering the operation of many plants. The study of this material will reward any operator.

Good results are obtained by careful control of the two principal elements in the filtration process—the preparation of the water by conditioning, coagulation and settling; and the maintenance and proper operation of the filter bed. The proper controls, gauges and operating mechanisms are essential in all plants.

Slow Sand Filters

The sand layer in a slow sand filter is ordinarily 30 to 40 inches deep; beds of fine sand may be shallower than those of coarse sand. The desirable depth is that which will provide the required degree of purification, and will also allow several scrapings or cleanings without reducing the depth of the bed below that which will prove effective. The loss of head is greater with fine sands, and filters built of them require more frequent cleanings.

The effective size of sand should range between 0.2 and 0.3 mm., and the uniformity coefficient should be between 2.0 and 3.0.

The depth of water normally maintained on the filters is 3 to 5 feet, though in some plants it is greater. This depth is maintained by means of rate-of-flow controllers which regulate the inflow of water to the bed and control the rate of discharge.

The control of the rate of operation is practically the only factor available to the operator of a slow sand filter since the character of the raw water and the period of sedimentation are beyond his control.

There is no standard loss of head which cleaning is considered necessary, it varies from 2 to 6 feet, usually being about 4 or 5 feet. Cleaning may be necessary, depending on the condition of the water at intervals of 2 to 10 weeks.

Cleaning the Sand.—When the loss of head is such that the beds must be cleaned, the water is drained down below the sand level so that men equipped with foot pads can walk on the surface. Using flat shovels, the surface sand is scraped off to a depth of ¼ to 1 inch. Removal of the sand may be by an ejector, a conveyor or by wheelbarrows operating on planks.

Placing a Cleaned Filter in Operation.—Filtered water from other beds or from the mains should be turned slowly into the underdrains of the cleaned bed until the water rises several inches above the sand surface. Raw water can then by turned in but the rate should be such that the sand will not be scoured. Filtration can then be started at a very low rate, gradually increasing over a period of several days—from four days when the filter has been scraped to a week after replacement of sand. During this period, and until tests show the quality of the water to be satisfactory, the effluent from this filter should be wasted.

Disinfection of Water

None of the steps in water purification — storage, sedimentation, coagulation and filtration — nor all of them combined can be relied on to remove all of the bacteria from the water, though ordinarily only 1% or less may survive these processes in a well operated plant. These remaining bacteria should be removed by disinfection.

Chlorination is the final safeguard of the quality of the water. As such the necessity for its continuous and regular application in sufficient amounts to accomplish bacterial removal cannot be overemphasized. This requires good equipment; attention, care and intelligence; and the employment of proper tests and checks.

Chlorine is employed primarily in the form of liquid chlorine, and in the smaller plants, as a solution of calcium hypochlorite.

Liquid chlorine is 100% available chlorine. Actually it is a gas, but under pressure it becomes a liquid in which form it is shipped in steel cylinders. The pressure varies with the temperature from 40 to 150 pounds, being greatest at high temperatures. At 70° F, the pressure is about 85 pounds per sq. in.

Calcium hypochlorite solutions are normally prepared from calcium hypochlorite powder which contains not less than 70% available chlorine and is quite stable. However, when the powder is exposed to the air, moisture will be absorbed from the air and a crust will be formed on the surface. Chlorine will be lost especially in warm rooms or climates, and therefore, the container should be tightly covered. When kept in tight containers, the powder may be stored for a considerable period of time with small loss of chlorine. Ordinary chlorinated lime or bleaching powder, containing 25% to 35% available chlorine, is much less stable and loses strength rapidly when exposed to air. When stored in tight containers, the chlorine content is lost more slowly, the rate of loss being around 1% per month.

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Valves and controls on a chlorine cylinder.

The requirements for equipment for applying chlorine to water are accuracy, within close limits, but most of all reliability, for if the application of chlorine fails, an unsafe water may result in serious epidemics.

Applying Liquid Chlorine

Liquid chlorine is applied to water by means of a chlorinator. The function of the chlorinator is to take the liquid chlorine from the cylinder, measure it, and feed it constantly in predetermined amounts into the water. Application may be in either of two ways, directly to the medium being treated, as a gas; or first mixing with water and applying the resulting solution. These two methods are known respectively as "direct feed" and "solution feed."

Direct Feed Application.—In a direct feed apparatus, the gas is applied through some type of diffuser, usually a carborundum stone, which divides the gas into very small bubbles, making it easily absorbed by the water.

Solution Feed Application.—In this method, which is used in most waterworks plants, the gas is dissolved in a small flow of water. The pressure of this water operates an injector which applies the chlorine solution against pressure in the pipe line. In operation, a practical minimum pressure ratio is 4 to 1, or 4 pounds in water pressure to the injector for every pound in line pressure.

Operation of a Chlorinator. — For proper operation, the room in which the chlorinator is kept should be not colder than 50° F. Warm gas entering a colder chlorinator will condense and may cause clogging. Therefore, the chlorinator should not be placed on an out-

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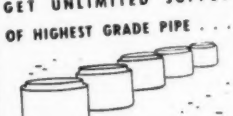

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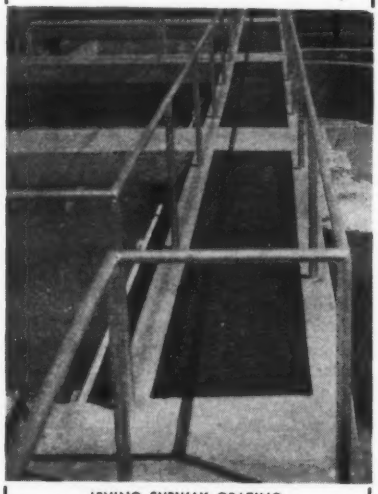

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side wall, but should be in a warmer place than the cylinder or the pipe connecting the cylinder and the chlorinator. A radiator, a small stove, or an electric heater may be used. The chlorinator building should be insulated or well protected. Chlorine cylinders should not be exposed to concentrated heat.

Chlorine cylinders should be kept on scales and the weight read each day as a check against the amount of chlorine used.

The maximum drawoff or discharge from 100 to 150 pound cylinders at 70° F is approximately 35 pounds per 24 hours. Due to the change from a liquid to a gas, a drop in temperature occurs and if more than 35 pounds are used daily, 2 or more cylinders should be attached.

A reserve supply of chlorine should be kept on hand; also a supply of duplicate parts, including valves, gaskets, etc. The operator should not attempt major repairs; it is far better to have an entire duplicate chlorinator on hand for emergencies.

Chlorine leaks are dangerous since the gas is irritant to the lungs. A concentration of 1 part of chlorine in 100,000 can be noticed; 1 part to 50,000 parts of air causes discomfort; and 1 part in 1000 of air after 5 minutes exposure produces death. Leaks can be located by means of an open bottle of ammonia. Valves, connections and other places that may permit chlorine to escape are tested with the ammonia bottle. White fumes of ammonium chloride are formed when chlorine combines with ammonia. Suitable gas masks should be on hand for use in case of leaks. Chlorine being heavier than air, ventilation at or near the floor level is desirable.

Dosage of Chlorine.—The dosage of chlorine required for making water safe depends on many factors. Waters that are turbid, or contain much organic matter, iron or manganese, may require large amounts. The chlorine residual test is the essential guide to the amount of chlorine required. Most waters are effectively treated when there is 0.2 ppm. or more of true residual chlorine in the water.

Using Hypochlorites

Hypochlorite solutions, prepared from high chlorine content hypochlorites, are used in the smaller water plants for chlorination of the supply, and in many plants hypochlorinators are used for standby and emergency work. Sodium hypochlorite solutions may also be used.

To make 40 gallons of 1% available chlorine solution, there will be required 40 gallons of water which weigh 333.6 lbs. Chlorine required is 1% of 333.6 or 3.336 lbs. If the calcium hypochlorite powder has a chlorine content of 70%, then 3.336 divided by 70%, or 4.76 lbs. of the hypochlorite powder will be required for 40 gallons of solution. As 70% available chlorine calcium hypochlorite is available in 5-lb. cans, a solution made by mixing one 5-lb. can of hypochlorite with 40 gallons of water may be considered as of 1% strength. This is not exact, but is near enough for all *practical* purposes.

As solutions lose strength on standing even in dark, cool places, only enough to last a few days should be prepared at one time.

Hypochlorinators. — Feeding equipment for hypochlorite solutions is available in a variety of forms. The type most used is a small motor driven diaphragm pump capable of easy variation of the stroke length, stroking rate, or both. This unit can be cross-connected on the starting switch of an electric pump so as to start and stop in step with it, thus providing automatic chlorination; or it can be plugged into an electric light socket and started and stopped manually. Other types are available for operation by water power from the main being treated, and both electric and water operated types can be obtained for control from meters.

Computing Dosages.—To chlorinate a flow of 500 gallons per minute with a dosage of 4 lbs. of chlorine per million gallons or 0.48 parts per million, using a solution containing 1% available chlorine, the required number of cubic centimeters to be added to the flow per minute is as follows: 4 lbs. of chlorine is contained in 400 lbs. of 1% available chlorine solution; $400 \div 8.34 = 48$ gallons of 1% solution per million gallons. Multiplying the number of gallons required per million gallons of water by the number of cubic centimeters contained in a gallon (3,785), 181,680 cc. of 1% solution are required per million gallons; or 0.1817 cc. per gallon. Multiplying the requirement per gallon by the flow rate, $500 \times 0.1817 = 90.85$ cc. of 1% solution per minute.

Ammonia—Chlorine

When water contains such industrial wastes, as phenol compounds, the addition of chlorine may cause disagreeable tastes; the same trouble may occur if algae are present in considerable quantity in the water.

If ammonia is added to the water just before the chlorine is added, the reaction between the chlorine and the taste-producing organisms is prevented, and much or all of the taste problem is eliminated. The use of ammonia also permits the use of larger doses of chlorine without causing chlorine tastes. The ammonia should be applied a few feet ahead of the chlorine so as to produce a thorough mixing of the ammonia with the water.

When ammonia and chlorine are used, the two chemicals combine to form chloramines which do not react as quickly with organic matter as does chlorine alone. Consequently, the rate of disinfection is slower, and a longer period of contact—about 2 hours—is required. Water treated with ammonia and chlorine should not be used, therefore, until 2 hours after treatment.

An advantage of the use of ammonia with chlorine, is that in small plants, without full-time attendance, where the flow or usage of water varies materially

from hour to hour, and where the chlorine dosage is not regulated by automatic equipment in accordance with the volume of flow, the heavier dosages during periods of low flow are less likely to cause tastes when both ammonia and chlorine are used.

Ammonia is ordinarily furnished in cylinders of the same type as are used for chlorine; and application is by means of equipment practically the same as that used for applying liquid chlorine. Chlorinators cannot be used since different construction is necessary to prevent corrosion. Ammonia can also be applied in a liquid form by ammoniators of the same general type as the hypo-chlorinators described above.

The dosage of ammonia required depends on the characteristics of the water. Ordinarily it is a third to a half of the chlorine dosage. When using ammonia, a higher chlorine dosage is commonly used.

Superchlorination and De-chlorination

Superchlorination of water, with or without de-chlorination, is effective in removing most tastes and odors, and furnishes additional protection against water-borne diseases. De-chlorination can be effected by several chemical reagents or by filtration through granular carbon. If the complete chlorine demand is satisfied and chlorinous tastes and odors are not objectionable, de-chlorination may be unnecessary unless the effect of free chlorine on manufacturing processes must be considered. Sulfur dioxide is the reagent most commonly used for de-chlorination, chiefly because of its low cost.

Break-Point or Free Residual Chlorination

When enough chlorine is added to water to satisfy completely its chlorine demand, a free chlorine residual results from further addition of the chlorine. This free chlorine residual is highly effective in destroying organisms in the water and also is persistent. It may be effective in eliminating tastes and odors, and in destroying organic growths inside the pipes of the distribution system; but most important, from the viewpoint of safe water, is its ability to destroy bacteria and to maintain safe residuals throughout the entire distribution system.

The chlorine dosage necessary to insure complete sterilization and a persistent residual, without tastes or odors, must be determined by preliminary laboratory works followed by trials on a plant-scale basis. Chlorine demands may vary according to the character of the water, seasonal and climatic conditions, and other factors. Therefore, it is desirable for a plant contemplating the use of this method of chlorination to call on the manufacturers of chlorinating equipment suitable for the work to assist in developing dosages. Bacterial elimination and the consequent protection at all times of the consumers are the most important advantages to be gained through the maintenance of free chlorine residual, but many cities report additional advantages. In most plants using this method, a free available chlorine residual of 0.8 to 1.2 gpm. is maintained on the filters.

To evaluate break-point chlorination possibilities for any given water supply, a series of procedures have been prepared by A. E. Griffin, and published by Wallace & Tiernan Co., as Technical Publication 213.

Chlorine Water, not hypochlorite, must be used. A suitable solution can be obtained from a chlorinator solution hose or by bubbling chlorine through water obtained from the laboratory tap. Due to the instability of chlorine water, fresh solutions should be made up daily and should be standardized immediately prior to the start of each test. It is preferable to use amber bottles for the chlorine water. Standardization is by titration with N/10 or N/40 sodium thiosulphate, either in accordance with Standard Methods of Water Analysis or by the method described in the pamphlet mentioned above. Strength of the chlorine water should be such that the volume of the treated sample will not be increased by more than 5%.

Chlorine Application. — Within certain limits the break-point is a function of the ammonia content of the water. Because of this, a convenient way for determining the approximate chlorine

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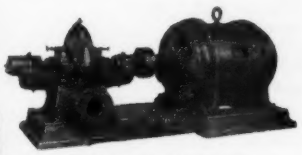

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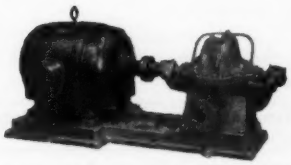

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PRODUCT	AVAILABLE FORMS	COMMERCIAL STRENGTH (MIN.)	SHIPPING CONTAINERS	APPLICATIONS
Aluminum Sulfate $Al_2(SO_4)_3 \cdot 14H_2O$ approx. *(Filter Alum)*	Commercial & Iron Free: Lump • Ground Powdered	17.25% Al_2O_3	Bags Barrels • Drums Bulk Carloads	Coagulant for water and sewage. Dewatering conditioner for sewage sludge. 1% Sol. pH 3.4.
Aqua Ammonia NH_4OH plus Water *(Ammonia Water)*	Colorless Liquid	26° Be. (29.4% NH_3)	Steel Drums Carboys	Used with chlorine to form chloramines for water disinfection.
Ammonium Aluminum Sulfate $Al_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$ *(Ammonia Alum) (Crystal Alum)*	Lump Nut Granular Powdered	11.2% Al_2O_3	Bags Fibre Drums	Coagulant for water. Advantageous for pressure filters. Supplies ammonia for chloramine formation. 1% Sol. pH 3.5.
Sodium Bisulfite, Anhydrous $Na_2S_2O_5$ *(ABS) (Sodium Metabisulfite)*	Powdered	97.5% $Na_2S_2O_5$ (Equiv. 65.5% SO_2)	Fibre Drums	Antichlor. Remove iron and manganese deposits from filter sand. 1% Sol. pH 4.6.
Sodium Silicate $Na_2O \cdot X(SiO_2)$ plus H_2O *(Water Glass) (Silicate of Soda)*	Viscous Liquid	38° to 52° Be. Various Ratios of Na_2O:SiO_2	Drums Tank Cars Tank Trucks	1. Aid in floc formation. 2. Prevent red water corrosion in distribution lines. 1% Sol. pH 12.7
Sodium Thiosulfate $Na_2S_2O_3 \cdot 5H_2O$ *(Hypo) (Sodium Hyposulfite)*	Crystals: Prismatic Rice Selected Universal Granular	99.75% $Na_2S_2O_3 \cdot 5H_2O$	Bags Barrels Fibre Drums	Antichlor. Water solution is neutral.
Sulfuric Acid H_2SO_4 plus H_2O *(Oil of Vitriol)*	Corrosive, oily liquid Various strengths	66° Be. (93.19% H_2SO_4)	Bottles Carboys Drums Tank Trucks Tank Cars	1. Reduce pH and alkalinity. 2. Regenerate carbaceous zeolites and ion exchangers. 3. Activate Baylis Silicate.
Potassium Aluminum Sulfate $Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$ *(Potash Alum)*	Lump Nut Granular Powdered	10.7% Al_2O_3	Bags Fibre Drums	Coagulant for water. Slow, even rate of solubility desirable for solution pot feeders. 1% Sol. pH 3.52.
Sodium Sulfite, Anhydrous Na_2SO_3 *("Sulfite")*	Granular Powdered	98.5% Na_2SO_3	Bags Fibre Drums	Antichlor, oxygen remover. Weak solutions absorb oxygen readily. 1% Sol. pH 9.8.
Sodium Sulfate, Crystal $Na_2SO_4 \cdot 10H_2O$ *(Glauber's Salt)*	Crystal & Needle Crystal	96% $Na_2SO_4 \cdot 10H_2O$	Barrels Bags Drums	Neutral Solution. Boiler water treatment (maintenance of sulfate-carbonate ratio).
Sodium Sulfate, Anhydrous Na_2SO_4	Powdered	99.5% Na_2SO_4	Bags Barrels	Neutral Solution. Boiler water treatment (sulfate-carbonate ratio)
Trisodium Phosphate $Na_3PO_4 \cdot 12H_2O$ *(TSP)*	Crystal	98.5—103% $Na_3PO_4 \cdot 12H_2O$ (Equiv. 19% P_2O_5)	Bags Barrels Fibre Drums	Boiler water treatment. Cleaning compound. 1% Sol. pH 11.8-12.0.
Disodium Phosphate, Crystal $Na_2HPO_4 \cdot 12H_2O$	Crystal	98% $Na_2HPO_4 \cdot 12H_2O$ (Equiv. 19.5% P_2O_5)	Bags Barrels Fibre Drums	Boiler water. (Calcium and magnesium precipitation.) 1% Sol. pH 8.4.
Disodium Phosphate, Anhydrous Na_2HPO_4	Powdered Flake	96% Na_2HPO_4 (Equiv. 48% P_2O_5)	Same	Same as Crystal, but stronger product.
Sodium Fluoride NaF *(Fluoride)*	Powdered (white or blue colored: Nile Blue) Light or dense	90% and 95% NaF	Bags Barrels Fibre Drums	Fluorination of water supplies. (For information, consult with local health officers.)

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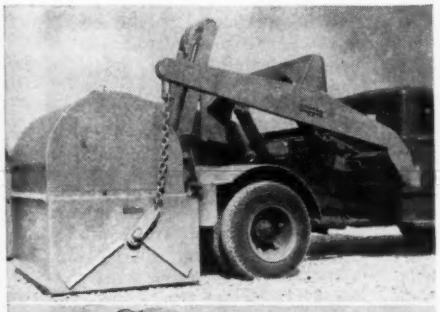

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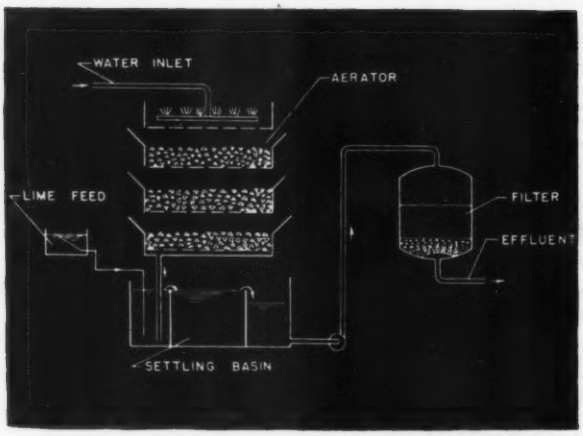

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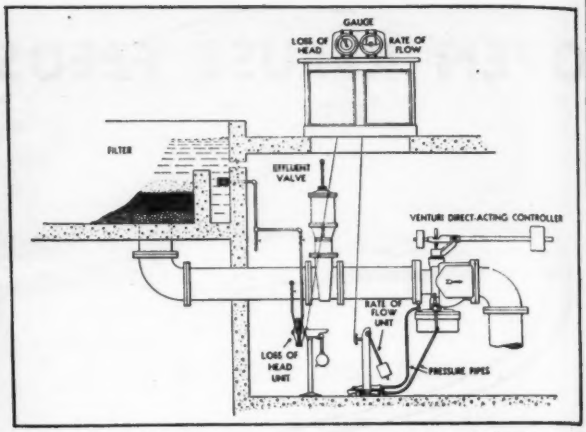

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How rate-of-flow and loss-of-head gauges control a filter.

application required to produce a "break-point" is to multiply the ammonia content by ten. Applications of chlorine should be so arranged as to cover a reasonable range on either side of this figure.

Contact.—Allow the sample to stand after addition of chlorine for a period equivalent to that provided by the plant sedimentation basin or clear well, whichever is to be utilized for break-point treatment. During testing, the sample should be kept at the temperature of the water in the plant and away from strong light.

Residual Chlorine.—At the end of the desired contact period, determine the residual chlorine in each sample. Orthotolidine may be used for residuals up to 1.0 ppm. For values in excess of 1.0 ppm. titration with sodium thiosulphate is recommended. Plot the results.

Tastes and Odors.—Taste and odor determinations should be made on all samples at the end of the contact period selected. It is desirable that these values be recorded at Threshold Units though the original standard methods procedure of taste and odor designation may be used where threshold odor equipment is not available.

A simplified and valuable procedure for the application of breakpoint chlorination to any plant is detailed clearly in the W & T publication mentioned above. This will be sent on request.

Residual Chlorine Determinations

After a water has been chlorinated, the presence of residual chlorine can be determined by the orthotolidine or the starch iodide tests. The former enables the operator to determine *how much* chlorine remains in the water; the latter indicates only that chlorine is present.

Procedure with Orthotolidine. — A standard orthotodiline solution is furnished by makers of chlorinating apparatus and by laboratory and chemical supply houses. A very light yellowish color reaction with this test indicates about 0.1 ppm., and the color deepens with the increase of chlorine. Color standards are necessary in order to read closely the amount of chlorine present.

When ammonia and chlorine are used in the treatment of the water, or when iron or manganese are present in sufficient quantity to interfere with the test, modifications are necessary in the procedure.

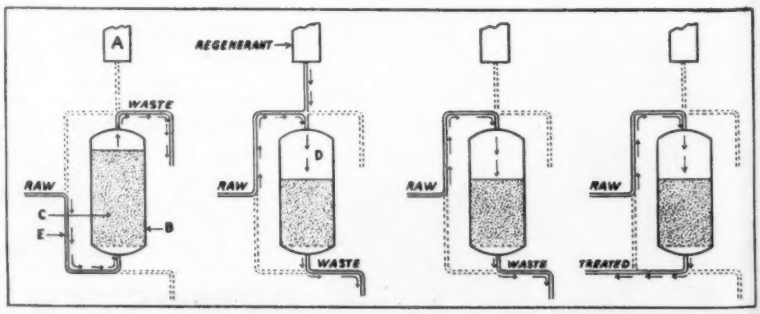
With Ammonia-Chlorine. — When both ammonia and chlorine are applied to the water, a longer period is necessary for the color to develop after the orthotolidine has been added. Instead of the 5 minutes when chlorine alone has been applied, a 10 to 30 minute period is necessary.

With Iron and Manganese.—If either of these minerals is present, a false color reaction occurs with orthotolidine, thus making the test for residual chlorine unreliable.

Since residual chlorine rarely persists for as much as 24 hours, two samples may be collected each day, one of which is tested at once and the other allowed to stand for 24 hours before testing. The apparent chlorine content of the latter is subtracted from the apparent chlorine content of the former to secure the approximate true residual. The OTA test also indicates the amount of interfering color from manganese, iron and nitrites.

Starch Iodide. — By this test, the presence of chlorine in the water is indicated by a faint blue color. The reaction takes place with a chlorine residual of 0.10 to 0.15 ppm. A rather deeper color is obtained with higher chlorine residuals, but the test is not really a quantitative one. A starch solution is purchased or made up in accordance with directions in *Standard Methods.*

The Laux test is an adaptation of the orthotolidine test. Special emphasis is given to the speed of color development when orthodolidine is added to the sample. From a practical viewpoint, free available chlorine reacts instantly with orthotolidine, regardless of the temperature. On the other hand, the reaction with chloramines is relatively slow, especially at the lower temperatures. Thus, the reading obtained immediately indicates the amount of free available chlorine present, and color developing thereafter approximates the amount of combined chlorine or chloramines. The test is most sensitive below 60° F; for higher temperatures, the samples should be cooled to or below 60° F prior to the test. Accurate results will depend on the timing of the readings; the first should be made in exactly 5 seconds, and the second exactly 5 minutes after the addition of orthotolidine. Since the 5-second reading shows the amount of free available chlorine, and the 5-minute reading, the amount of total residual, the difference between the two readings will show the chloramine present, con-



Courtesy Gen. Filter Co.

Flow diagram showing backwash, charge, rinse and service of zeolite water softener.

sideration being given to the presence of interfering substances.

The OTA test determines the amounts of free available chlorine and chloramine present and will automatically compensate for interfering colors produced by manganese, iron and nitrites. This test can also be used to determine the exact amount of interfering color. Precision of results depends upon strict adherence to test procedures: (a) the time intervals between addition of reagents; (b) the relative concentration of free available chlorine and of combined available chlorine in the sample; and (c) the temperature of the sample, which should never be above 20° C (68° F). The precision of the test increases with decreasing temperature. Details describing performance of these tests will be found in Standard Methods (Text 1).

Disinfecting Mains and Reservoirs

Water mains should be protected against contamination while they are being installed; dirt and other material should be removed before laying. Before being placed in service, every section of pipe should be flushed out and then chlorinated, using a dose sufficient to give 50 ppm. of residual chlorine with a contact period of at least 12 hours. If oakum or jute is used for caulking the joint, it should be thoroughly disinfected, preferably by heat. It is better to use some of the bacteria-free products now available for making joints. A quaternary ammonia has been used successfully for main sterilization, but dosage is high and contact period long.

When liquid chlorine is used, a corporation cock is inserted in the old line near the connection to the new line, and a special stuffing box is inserted and connected to a chlorine cylinder with a silver or copper tube. The stuffing box and tube can be obtained from manufacturers of chlorinators; also special chlorinators for this purpose are available and are preferable.

The line is flushed out; after it has drained, water is then turned into it slowly, and chlorine gas from the cylinder is turned into the main. Water pressure should normally be below 30 pounds.

A chlorine solution can be used instead of liquid chlorine, in which case it can be forced into the main with a pump or added to the water entering the main.

When using bleaching powder, 25% available chlorine, the following amounts are required for each 100 feet of pipe: 4-inch, 1½ ounces; 6-inch, 3½ ounces; 8-inch, 6 ounces; 10-inch, 10 ounces; 12-inch, 15 ounces; 16-inch, 30 ounces. When using HTH or Perchloron, 40% as much is sufficient; AWWA Standards suggest 1 pound (70% available chlorine) for each 1680 gallons of pipe capacity to be treated.

When the bleach is placed in the pipes as they are laid, the line is filled slowly with the water and allowed to stand for 12 hours; it is then flushed

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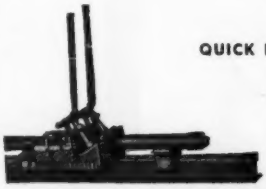

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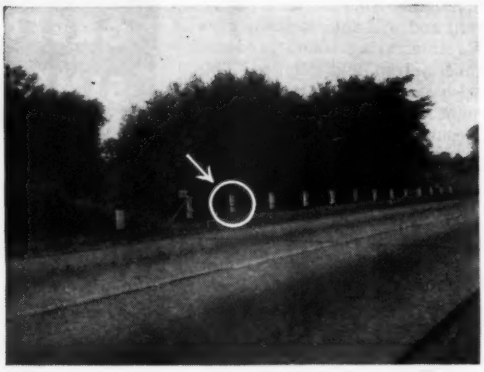

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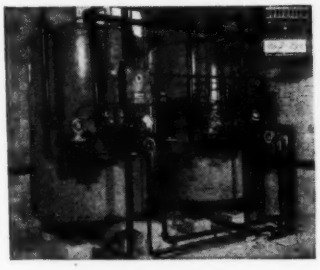
CONDITIONED BY PERMUTIT

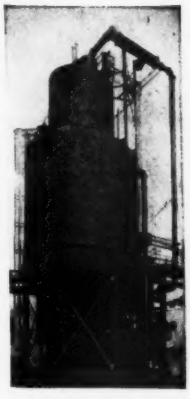
ZEOLITE WATER SOFTENER

The zeolite process—originated by Permutit—is the *simplest method* of removing hardness from water. Original cost of equipment is lower than that of any other form of water softening. Permutit's *electric-automatic* zeolite water softeners backwash, regenerate and soften water automatically under positive electrical control. It's the last word in simple, effective, and efficient water conditioning.



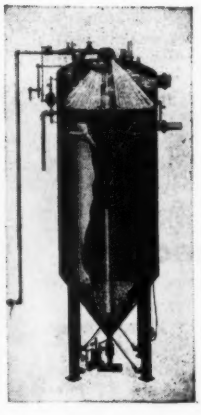
DEAERATING HEATER

Stops corrosion! Permutit Deaerating Heaters are guaranteed to remove all oxygen (Winkler test) and free CO_2 from feedwater. Spraying the feedwater through steam removes most of the oxygen and free CO_2. Deaeration is completed when the preheated water is boiled briskly in the steam scrubber. Bled or exhaust steam is utilized for the entire operation. Boilers are kept rust-free, in top operating condition, year after year with the modern Permutit Deaerating Heaters.



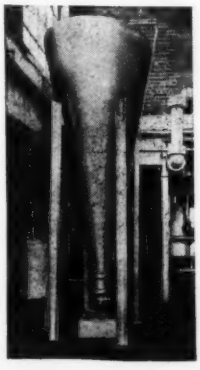
SLUDGE BLANKET HOT PROCESS

This process reduces turbidity of softened water, lessens the load on filters, cuts backwashing, and *lowers the amount of silica!* Permutit's development and application of the sludge blanket design in water softening effects considerable chemical savings because of its low consumption of lime and the expensive phosphate reagent. The Permutit Sludge Blanket Hot Process attains a more complete, efficient softening reaction at lower costs.



PRECIPITATOR

Permutit's Precipitators remove turbidity, taste, color, odor, alkalinity, hardness and other impurities. Much less space, detention time and chemicals are required compared to conventional designs of reaction and settling tanks.



SPIRACTOR

Permutit's sludgeless cold lime spiractor softens water *20 times faster* than old style conventional type treating systems. The chemically-treated water enters from the bottom, flows upward through a suspended catalyst bed of calcium carbonate granules. Precipitates form as a result of the water softening reaction, and are deposited on the catalyst granules by accretion. The effluent is a soft, low-alkalinity water suitable for filtration as required.

IRON REMOVAL

For pressure or gravity systems, Permutit supplies equipment that removes iron and manganese . . . equipment designed to do the most efficient job at least cost.

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Permutit

FOR 35 YEARS WATER CONDITIONING HEADQUARTERS

thoroughly. A serious disadvantage of this method is that the end of the line at which water is admitted is not adequately treated, since most of the bleach is washed to the lower end by the inflow of water. This method should not be used if the method previously described is possible.

Orthotolidine tests are made on the water as it comes out of the valve or hydrant at the far end of the line. When a deep yellow color is obtained by the test, allow the line to fill, shut off the chlorine, and the value admitting water to the new line. Allow to stand for 12 hours, and flush thoroughly. If there is no valve or hydrant at the lower end of the line, a testing plug fitted with a stop-cock can be placed in the end of the pipe line, to permit the discharge of air as the line is filled with water, and also to permit taking samples of water for orthotolidine tests.

Filters, elevated tanks, concrete or steel reservoirs, and other similar structures, should also be treated before being placed in service. Liquid chlorine may be added to the water as these are being filled; ½ to 1 pound of bleaching powder, 25% available chlorine, may be used for 1000 gallons of water. State Boards of Health will furnish detailed directions for procedures for each individual case.

Safety Measures When Using Chlorine and Ammonia

In addition to the precautions already outlined in regard to the use of chlorine and ammonia, a gas mask should be available in a room not connected to the chlorine or ammonia application or storage rooms. Not all gas masks protect against ammonia. Read carefully the statement on the gas mask canister to be sure that it will protect against both gases. A first aid kit should also be kept readily available.

Safeguarding Water Quality

Merely to produce a safe water by the methods described above is not sufficient: it is necessary also to insure that the water reaching the consumer is safe. Connections to unsafe supplies constitute the principal hazard; but plumbing fixtures subject to back-siphonage, and negative pressures or vacuums in pipe lines also may contribute to the danger.

Adequate ordinances governing cross connections and types of plumbing, plus a comprehensive inspection and educational program will eliminate many of the hazards due to such causes. The State Sanitary engineer will be glad to advise and to assist in such a program.

Negative pressures in pipe lines may permit the entrance of contamination through imperfect joints or broken sections of pipe. To prevent such negative pressures the treatment plant should be ample in capacity to meet the peak demands for water; mains and submains should be large enough to supply all sections of the community at times of maximum demand; and elevated tanks and reservoirs should be provided to insure the maintenance of safe pressures throughout the community. Perhaps most important of all is to maintain in the entire distribution system, at all times, a perceptible chlorine residual in the mains.

How Hard Water Is Softened

The causes of hardness—calcium and magnesium compounds — have been listed. In the amounts ordinarily present in water, these chemicals do not affect health, but they interfere with the use of water for many business, domestic and industrial uses. Hardness greatly increases the amount of soap used; reduces the efficiency of hot water heaters and boilers by depositing scale on tubes and heating surfaces; and may hinder the operation of laundries, textile plants and other industrial processes.

Softening is usually effected by one of two processes: The addition of lime and soda ash, which changes the bicarbonates and sulphates of calcium and magnesium from soluble to insoluble forms, and the removal of these by sedimentation and filtration; and by passing the water through a bed of zeolite, which transforms the calcium and magnesium salts into sodium compounds which do not cause hardness.

Lime-Soda Softening

Lime is added to remove carbonate hardness and magnesium; soda ash is used to remove the non-carbonate hardness. Data required are: Free CO_2; half-bound CO_2 which is 44% of the bicarbonate alkalinity; total magnesium; and non-carbonate hardness. These should be expressed in parts per million.

The free and the half-bound CO_2 are added together; 10.62 pounds of pure CaO are required per million gallons to neutralize each part per million of free and half-bound CO_2. The lime required to react with magnesium amounts to 19 pounds of CaO per million gallons per part per million of magnesium. For the removal of non-carbonate hardness, 9 lbs. of soda ash are required per million gallons per part per million of non-carbonate hardness, expressed as $CaCO_3$.

It is usual to leave in the water a carbonate hardness of 35 ppm. to 50 ppm. and a total hardness of 50 to 100 ppm. In practice this amount should be subtracted before computing the chemical dosage.

Jar tests, already described, may be used to check the calculations of lime and soda ash. The chemical equations developed in lime-soda softening and methods of computing dosages are described fully in Text (3), Water and Sewage Chemicals and Chemistry.

Recarbonation.—When water is softened with lime, some of the carbonates may remain in suspension in the water, and precipitate on the sand grains of the filter or in the piping of the distribution system. This is especially the case when the excess lime softening treatment is used, which consists of overdosing the water with lime—35 to 50 ppm. excess of lime—resulting in a very rapid formation of flocculent matter.

This excess dosage of lime results in a caustic alkalinity. The addition of carbon dioxide will remove the caustic alkalinity by changing the calcium hydroxide to calcium carbonate. This is known as recarbonation.

The CO_2 for the small plant is generally produced by burning gas, oil, coke or coal; stack or produce gases can be used. For burning oil, gas or coke, a small stove may be used, the gas from which contains about 10% of CO_2. This gas must pass through a washer, a drier, a trap for further removal of the moisture and a compressor or blower, which forces it through a grid or diffuser into the water. Porous diffuser plates reduce the required depth of basins and the power cost of CO_2 diffusion.

The theoretical amount of CO_2 required in pounds per million gallons is 3.7 times the parts per million of calcium carbonate; in practice 25% should be added to this. A plant with a capacity of 1 mgd. will ordinarily not require more than about 500 pounds of CO_2 daily or about 30 cubic feet per minute of gas. A discussion of this subject is given in Water Supply and Treatment, by Charles P. Hoover, published by the National Lime Association.

Zeolite Softening

Zeolites are mineral compounds which have the ability when water is passed through them, to remove the hardness. In reality this is an exchange. The zeolites normally have a sodium base, but when water containing calcium and magnesium is passed through the zeolites, the sodium is given up and its place is taken by the calcium and magnesium which are taken from the water. When all the sodium has been replaced by calcium and magnesium, the zeolite must be regenerated, which is accomplished by passing a strong salt solution through it. The calcium and magnesium are then exchanged for sodium and the bed of zeolite is again ready for softening water. This process is continued indefinitely.

The zeolite is usually placed in a steel tank similar to and operating like a pressure filter. The bed of zeolite is usually 30 to 60 inches thick. The washing system is generally the same as in a rapid sand filter, though the rate of wash is usually lower—from 6 to 8 gallons per square foot per minute.

Operation.—The rate of operation is ordinarily 4 to 6 gallons per square foot per minute. The zeolite is not intended to act as a filter, nor to remove suspended matter from the water. Consequently only clear water should be passed through the zeolite, and in the

case of filter plants, softening will normally follow filtration.

The rock salt for regenerating the zeolite is made into a brine. As applied to the zeolite for regenerating, the brine should contain not more than 10% nor less than 5% of salt. In regenerating, the incoming water is shut off, the outlet closed, the unit backwashed, and the brine introduced. It is either held in contact for 10 to 15 minutes or circulated slowly through the bed. Zeolites will soften water to zero hardness, but this is not often desirable, and a hardness of 50 to 70 ppm. is generally permitted. This is usually accomplished by softening completely a part of the water and mixing this softened water with enough raw water to obtain the desired results.

Algae Identification and Control

Plant growths of the algae type may create trouble by causing tastes and odors, by giving the water a colored appearance, and by tending to clog filters or other treatment processes. In addition, other microscopic organisms in water may contribute to these troubles or cause some all their own.

The microscopic organisms in water include the algae and fungi, which are plants; and the protozoa, rotifera, crustacea and vermes, which are animals.

The term *plankton* is often used to designate the above organisms. Strictly speaking, the term refers to organisms that float free in the water, but it has been extended to include those organisms, exclusive of bacteria, that are found in the open waters of lakes and streams.

Algae.—There are six commonly recognized classes of algae: Cyanophyceae, or blue green; chlorophyceae, or green; xantophyceae, or yellow green; diatomaceae, or diatoms, usually brown, the phaetophyceae, or brown; and the rhodophyceae or red. Each of these classes are still further subdivided.

It is necessary that treatment be based on actual knowledge of algae growth conditions. This is best obtained by a microscopical examination to determine the kind and number of organisms in the water. With such knowledge, treatment may begin as needed; but if facilities for this examination are lacking, algae control, in the northern part of the United States, should generally start about May 1 and continue till nearly Nov. 1.

Microscopical Examinations for Algae Growths.—A sample of about two liters of the water should be taken from a point where the organisms will be as representative as possible. The container should be inserted with the neck downwards about a foot below the surface of the water, then inverted and allowed to fill. For greater depths, special sampling devices are necessary. The sample should be examined within 6 to 8 hours; if this is not possible, it should be preserved by adding 20 ml. of formalin to each liter of water in the sample.

If the sample of water contains a large number of organisms, it can be examined microscopically without concentration. If the number of organisms is small, the sample should be concentrated by filtering or centrifuging. The Sedgewick-Rafter method of concentration is simple and inexpensive.

The microscope used should be capable of magnification of from 60 to 400. The degree of magnification used depends upon the type of organisms present and whether the organisms are being counted or identified.

Methods for microscopical examination of water are covered in detail in *Standard Methods of Water Analysis*. The identification of algae types requires considerable experience and at first will require reference to illustrations of the various types. A complete treatment, and a large number of illustrations will be found in *Microscopy of Drinking Water* by Fair & Whipple.

Copper Sulphate Treatment

Prevention or control of algae is necessary in both storage and distributing reservoirs. Algae growths may be killed by the use of copper sulphate or chlorine. The latter, while easy to apply within a treatment plant, is quite difficult to apply in reservoirs, consequently copper sulphate is almost universally

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IRON PIPE OUTLET

MUELLER THREAD INLET
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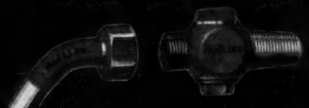

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What Type Connections Do You Need?

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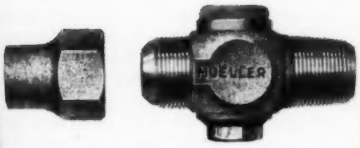

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Copper Sulphate Required for Treatment of Microorganisms[1]

Organism	*Odor*	*PPM.*	*Lbs. per M.G.*
Asterionella	Aromatic, geranium, fishy	0.12-0.20	1.0- 1.7
Synedra	Earthy	0.36-0.50	3.0- 4.2
Tabellaria	Aromatic, geranium, fishy	0.12-0.50	1.0- 4.2
Eudornia	Faintly fishy	10.0	83.2
Hydrodictyon	Very offensive	0.10	0.8
Pandorina	Faintly fishy	10.00	83.0
Volvox	Fishy	0.25	2.1
Anabaena	Moldy, grassy, vile	0.12	1.0
Aphanizomenon	Moldy, grassy, vile	0.12-0.50	1.0- 4.2
Clathrocystis	Sweet, grassy, vile	0.12-0.25	1.0- 2.1
Coelosphaerium	Sweet, grassy	0.20-0.33	1.7- 2.8
Cylindrospermum	Grassy	0.12	1.0
Ceratium	Vile	0.33	2.8
Cryptomonas	Candied violets	0.50	4.2
Dinobryon	Aromatic, violets, fishy	0.18	1.5
Glenodinium	Fishy	0.50	4.2
Mallomonas	Aromatic, violets, fishy	0.50	4.2
Peridinum	Fishy, like clam shells	0.50-2.00	4.2-16.6
Synura	Cucumber, muskmelon, fishy, bitter	0.12-0.25	1.0- 2.1
Uroglena	Fishy, oily, cod liver oil	0.50-0.20	0.4- 1.6
Beggiatoa	Very offensive, decayed	5.00	41.5
Crenothrix	Very offensive, decayed	0.33-0.50	2.8- 4.2
Sphaerotilis natans	Very offensive, decayed	0.40	3.3

used for algae control in these. In the table herewith the more troublesome algae types are listed, with their odor characteristics, and the amount of copper sulphate required for treatment.

An adequate dosage of copper sulphate should be applied as insufficient dosages are ineffective. A concentration sufficiently high to be injurious to health would have such a disagreeable taste that it would be practically impossible to drink it. However, the dosage necessary for control of algae may be sufficient to kill fish. Therefore, if fish are present in the water to be treated, it is advisable to consult the table herewith which shows the resistance of various species of fish.

Dosage of Copper Sulphate Likely to Kill Fish[2]

Fish	*Parts per Million*	*Pounds per Million Gallons*
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.36	11.1
Black Bass	2.00	16.6

Application of Copper Sulphate

Four forms of copper sulphate are available for use: Lump crystals, commonly known as bluestone; granular; snow or fine granular; and powder. Most algae and other microorganisms which cause tastes and odors are found in the upper 10 feet of the water where sunlight is strongest. Therefore, better results frequently may be secured by using powdered copper sulphate to destroy organisms near the surface, and the "snow" or granular material for deeper-lying organisms, because the larger granules sink into the water for an appreciable distance before dissolving.

The most common procedure in applying copper sulphate is to place the crystals in bags which are then dragged around behind a boat, generally following a criss-cross pattern. This is not always fully satisfactory. Syracuse, N.Y., has devised an apparatus by which water is pumped from the lake into a dissolving drum into which copper sulphate crystals are fed. The water dissolves the crystals and the solution is then sprayed onto the water. A width of 40 to 50 feet is treated. Newburgh, N.Y., uses a blower to scatter the dry crystals from the rear of a boat. The "snow" grade is used for light applications, the granular grade for heavy dosages; and combinations as needed.

Liberty, N.Y., also uses a duster for summer application, but has utilized another variety of copper sulphate—the monohydrate, which is especially adapted to blowers. For winter application through the ice, an outboard motor was lowered into the water, a bag of crystals placed behind the propeller, and the whole rotated so as to cover the entire circle around the hole. Tests indicated that effective dosages could be obtained by holes cut 1000 feet apart. An extension must be placed on the propeller shaft to allow lowering to the desired depth.

Methods of Taste and Odor Control

Tastes and odors do not cause disease and rarely indicate dangerous contamination. But when they render a supply unpalatable, the consumer is likely to turn to other supplies, often less safe. To protect the health of the community by furnishing a safe and a palatable water at all times is the duty of the water official. It is also good business.

Sources of Tastes and Odors

The most common sources of tastes and odors in water supplies are plant growths of the algae type. Some of these organisms exude oils or decomposition products which impart a disagreeable taste to the water, especially in combination with chlorine. Decaying vegetation, as leaves, grass and moss, is often a contributing cause. This cause is particularly evident when reservoirs are low, and contain swampy or stagnant areas.

Severe and troublesome taste and odor conditions may be due to industrial wastes from coke plants, chemical plants, canneries, tanneries, oil refineries, and dairies.

Determination of odor may be made with the water either hot or cold—the former giving the more positive results. The intensity and quality or kind of odor is, of course, largely a matter of personal opinion, but trained "smellers" will often agree quite closely.

Cold odor is determined by filling a bottle or flask (capacity about 300 to 500 ml.) half or two-thirds full, with water at room temperature (20° C.), shaking violently, removing the stopper and smelling.

Hot odor is determined by heating about 200 ml. of water in a 500 ml. flask, the neck being covered with a watch glass, to 65° C., shaking, removing the cover and smelling.

The "Threshold Odor" test is commonly used in determining intensity of odor. If an odor is detected in the sample, add 200 ml. of odor free water to 200 ml. of the sample, thus diluting it to 1 in 2. This procedure is repeated, until a dilution is reached below which odor is not readily detectable. Then starting with the sample of greatest dilution, test the samples in order until one is reached in which odor is just detectable. This is the threshold odor and is recorded as the odor concentration.

If hot odor tests are made, separate dilutions are necessary. Odor characteristics are listed in *Standard Methods*, which should be consulted for details of the above tests.

Methods of Control

The prevention of tastes and odors in the water may be accomplished by preventing the formation or growth of substances that may cause taste, as in the case of algae; by preventing the entrance of industrial wastes into the supply; by neutralizing or destroying the taste and odor-producing substances; or by removing them. Local conditions will usually determine which of these methods or combinations of them will be most effective and economical.

Preventive Measures in Raw Water.—Every measure possible should be taken to eliminate at the source all conditions tending to cause tastes and

[1] Hale, Frank E., 'The Use of Copper Sulphate in Control of Microscopic Organisms," Nichols Copper Co., New York.

[2] Moore, G. T., and Kellerman, K. F. Bul. No. 76, Bur. Plant Indus. U. S. Dept. of Agri. (1905).

odors. An early step should be a complete and thorough survey of the entire watershed to determine the points where pollution may originate.

Treatment Methods

Aeration.—By exposing a large surface area of the water to air, aeration liberates such gases as hydrogen sulphide and carbon dioxide from the water and permits the oxygen in the air to come into more intimate contact with the finely divided water particles, thus increasing the dissolved oxygen content of the water. This increase of oxygen content tends to remove the offensive tastes and odors by oxidation.

The general types of aerators in use include: (1) The cascade type, where the water is allowed to flow over successive sets of weirs. (2) The diffusion method, which consists of blowing air under a slight pressure through porous plates. (3) The spray method, in which the water is discharged under pressure through nozzles so that the water is forced into the air in a fine spray. (4) The surface contact type, which consists of coke-filled trays through which the water is passed.

Aeration affects only a few of the taste-producing elements. It should be used only after analyses and investigations of the water have shown clearly that aeration will be effective under the conditions that actually exist.

Activated Carbon.—Activated carbon may be used in either powdered or granular form. In industrial and a few municipal plants, the water is passed through a bed of granular carbon. In the majority of municipal plants, the powdered form is utilized, the carbon being applied by means of dry feed machines, solution feed machines or mixed with other chemicals. In dry feeding, equipment specifically designed for this material should be used, since activated carbons are much lighter and finer than other chemicals commonly employed in water treatment.

Points of Application.—Where filter plants are a part of the purification process, activated carbon is applied at any point prior to the filters. It may be applied as slurry directly to the water on top of the filters; to the filter influent; part way through the coagulation basin; at the extrance to the coagulation basin; in the mixing basins; or to the raw water. In general the points of application are divided into two general classifications, namely, prior to coagulation, and following coagulation.

If applied after coagulation the activated carbon will have the least work to do, since there is usually some elimination of tastes and odors during the sedimentation process. This point of application is recommended: (1) where tastes and odors are of short duration; (2) where tastes and odors appear suddenly and have not been noted until they have penetrated fairly well through the plant; (3) where tastes and odors are very mild.

Application prior to coagulation insures a longer contact time for the carbon to do its work. This point of application appears to be most suitable for the following: (1) where tastes and odors occur continually or frequently; (2) where the organic content of the water is relatively high and may cause tastes and odors due to decomposition within the plant itself; (3) where tastes and odors are of a severe nature, requiring heavy dosages of activated carbon. A split treatment may be preferable for serious tastes.

Dosages of Activated Carbon.—The required dosages of activated carbon have varied from as low as 1 lb. per million gallons to as high as 1000 or more lbs. per million gallons. However, calculations based on a survey made some years ago by PUBLIC WORKS indicated that the average dosage was approximately 16 lbs. per million gallons.

Trencher Saves Money on Water Line Construction

Costs of construction of water lines in 1947 did not greatly exceed 1941 costs, according to an article by S. S. Anthony, Superintendent and Engineer of the Augusta, Me., Water District, in the *Maine Water Utilities Ass'n. Journal*. The principal reason for this saving was the use of a ladder type trencher and a small crawler tractor equipped with a front-end loader.

For example, the use of the trencher permitted excavation of a trench 30" wide and 5½ to 6½ ft. deep for about 26¢ per foot. Average excavation in hard, compact, gray clay, was 117 ft. per hour, including some idling time and movement to and from the job. On another job in rocky ground, the average was only 24 ft. per hour. The tractor backfilled at an average of 53 ft. per hour at a cost of 2¢ per ft. On one job, the trencher, tractor and 7 men excavated the trench, laid the pipe, turned on the water and backfilled the trench in 6 hours for 468 ft. of 6-inch pipe. The tap had been made the day before and the pipe was laid out along the line of the trench.

The average cost on 4241 ft. of 6" and 2246 ft. of 8" cement lined cast iron pipe, fourteen projects, was $3.46 per ft. In 1941, 3006 ft. of 6" and 2850 ft. of 8" averaged $3.34 per ft. For 6" pipe only, the 1947 average cost was $3.05 per ft.

The cost charged against the equipment included overhead, repairs and maintenance, and operation.

Inter-American Ass'n of Sanitary Engineers

A conference of leading sanitary engineers was held Dec. 18, in the McGraw-Hill Bldg., New York, with E. J. Cleary, Executive Editor of Engineering News-Record, as host. The next conference will be held in Chile. Dr. Gordon M. Fair will be the principal delegate. There are now 986 members of the associations, 251 of whom reside in the United States.

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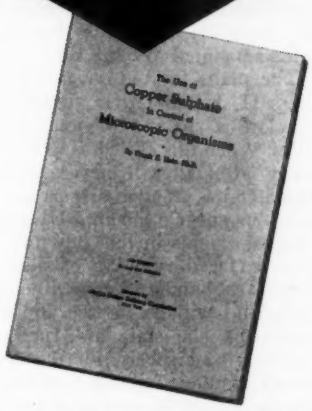

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Public Works Engineering Methods and Data

Minnesota's Municipal Airports

Construction work on 27 secondary and 16 primary airports is planned for this year in Minnesota. The plan for secondary airports contemplates the development of safe and usable Class I sod fields or landing strips adjacent to the smaller communities. In the thinly settled areas, these will be along the natural flyways, and it is hoped to develop enough of them so that ultimate spacing will be 15 to 30 miles apart. Service facilities will be available at most of them. Initially, the task is to get these small fields open as soon as possible. State aid for engineering and construction for the 3-year period ending Dec. 31, 1948, for these small fields amounted to $271,117.

The plans for the development of Class II, III or larger airports contemplate a spacing of roughly 100 miles. When this system is completed, heavy aircraft will never be more than 50 miles from an airport safe for that type of equipment. Ultimately all of the fields in this category will have surfaced runways of adequate length to handle feeder line type traffic and will be lighted for night operation. The state aid funds for this type of airports, for the 3-year period mentioned above, is $884,351. The League of Minnesota Municipalities, Minneapolis, has a list of the above-mentioned 43 airports, with data on present and planned conditions.

Pipe Line Protection Under a Highway

Construction of a new highway required the lowering of a 10-inch water line at Warren, Pa. This work was described briefly by C. C. Arbogast, Manager of the American Water Works & Electric Co. plant there in a recent issue of *Water*. It was necessary to remove 28 lengths of pipe, and the new cut varied from 15 to 30 ft. deep. The trench was dug with a 42-inch backhoe, by contract. To protect the main under the heavily traveled highway, the pipe was placed inside a 24-inch reinforced concrete conductor pipe. This was laid on sufficient slope to permit drainage, and the ends were sealed, with a small drain opening on the lower end. The concrete pipe was carefully laid and the backfill tamped around it. The 10-inch water main was assembled a length at a time and pulled through the 24-inch conduit pipe by means of a cable and block with hand winch.

Placing 84-inch Sewer Pipe

Concrete pipe, 84-ins. in diameter, was used in constructing the Slago Run sewer, Zanesville, O. The pipe was furnished by Universal Concrete Pipe Co. in 5-ft. lengths, each section weighing about 11,500 pounds. The sections were hauled to the job on a truck-drawn trailer, and were lowered into the trench, and placed, by means of a power crane. The joints on this project were of the tongue-and-groove type.

Maintainer Does Many Jobs on Runway Construction

In constructing a runway for B-36 planes at Patterson Field, near Dayton, Ohio, a Huber maintainer was used for transferring forms from hauling wagons to the form trench. On this machine, the 8-ft. pole of the front-end loader was used as a boom. The forms were 21″ by 25″, specials, 12 ft. long, and weighed 850 pounds per section. A total of 4,000 ft. of forms were used on the project. The runway is 10,000 ft. long, 300 ft. wide and 21 ins. thick. After the concrete had set, the side bar attachment on the maintainer was used to pull the form pins; the forms were then picked up and loaded into the wagons for movement. The work was done by W. E. Johnson Construction Co., Columbus.

Solving the Parking Problem in Fond du Lac

Last year the city of Fond du Lac, Wisc., made surveys to determine (1) how many cars needed parking space; (2) who owned them; (3) what the owners might be doing while parking their cars. The fact that 75% of the cars parked along the streets were from outside the city demonstrated that the first job was to find off-street parking areas. As a result, the city has purchased or rented, and improved five parking lots, or is working on the improvement. When these have all been completed, there will be free parking spaces for 1,500 cars, while private parking lots will care for 500 more. Parking along curbs is now rigidly restricted to 1 hour in the main business area.

Sludge Sales by San Diego

During the year ending June 30th, 1947, San Diego, Calif., produced at its sewage treatment plant 1,249 tons of fertilizer. All of it was sold, part to other city departments but most of it by contract at $20 per ton FOB plant storeroom, the sacks being furnished by the contractor.

Huber maintainer moving forms on runway construction.

Highway and Sanitation Equipment Repair Procedures

ROBERT K. SAWYER, Director
Bureau of Municipal Research of Philade'phia

The first installment of this article was published in the February issue.—Ed.

Before the war many cities throughout the United States had preventive-maintenance programs, designed to keep vehicles from breaking down. Most of these worked on the basis of periodic inspections usually every 1,000 miles or every month, whichever was shorter.

Among the 11 cities observed in this study, only Chicago, Milwaukee, and Washington now have such programs. The others have abandoned them or never started them. This has been generally due to large repair loads on old equipment during the war. All these cities have periodic greasing and some other periodic services, but have not yet installed complete programs.

Except in Philadelphia, Detroit, Pittsburgh, and Minneapolis, the organization heads plan to renew or start preventive-maintenance programs. New York, for example, will apply its very complete program, abandoned because of the repair load during the war, to its new equipment. The heads of shop organizations in Philadelphia and Detroit expressed the opinion that about double their present personnel would be required for such programs. In Minneapolis the shop head is satisfied with a fairly complete servicing program. Pittsburgh is undergoing organizational changes, and its plans are indefinite. Cities which previously had preventive programs generally felt them to be very worth while.

Unit Repairs and Reclamation Activities

Replacement of damaged units with new or reclaimed units has enabled many shops to reduce the length of time vehicles are out of service. For this reason, most shops are doing extensive unit replacement and repair work. In Philadelphia and St. Louis, where units are not extensively stocked, unit replacement is not generally practiced, though both cities have unit repair facilities and use them.

Some unit repair work is contracted for in several cities, usually because of lack of facilities or personnel, but occasionally because of an insufficient amount of such work to justify the shop equipment required. Items for which repair work is most frequently contracted are radiators, engines, carburetors, and generators.

Vehicle Operation

Both equipment and equipment operators are generally under the control of the using service. However, in Milwaukee, Minneapolis, and the Borough of Manhattan, neither equipment nor operators are under control of the using service, and in Detroit, the equipment is not under the control of the using service although operators are. It will be noted that two of these (Milwaukee and Minneapolis) are cities which have self-supporting repair organizations. As a rule, equipment is rented with an operator in these cities.

There is a wide variation in responsibility for daily servicing, such as gassing, washing and checking oil, tires, and batteries. In five cities regular shop servicemen do this work or most of it. In other cities the drivers do daily servicing, though washing responsibility varies.

None of the cities observed has a vehicle pool. In one sense, however, there are pools in those cities, like Milwaukee and Minneapolis, where shops are permitted to rent private equipment without special authorization. However, this is limited to kinds of equipment generally used by private concerns. All cities, except Philadelphia, Cleveland, and Newark, have some reserve equipment, and Newark will procure a reserve with a bond issue that was recently approved. Almost all the cities visited are either planning replacement pools or have them for special-purpose equipment, and a few are planning to have, or already have, limited pools for general-purpose equipment.

Roadside Repairs and Accidents

Calls for roadside repairs and accidents are handled by the shop organizations in every city, although the using services make numerous field repairs in Philadelphia, Pittsburgh, and possibly some other cities.

Tire replacements represent the majority of roadside services on refuse-collection and street-cleaning equipment. In Philadelphia, most of the tire exchanges are made by the using service. Frequently, because the Department of Supplies and Purchases limits the number and kind of tires stored by using services, and provides no field service itself, it is necessary to take vehicles out of service for many hours for tire repair.

Several cities, notably Chicago and Minneapolis, are using special trucks for tire service. One of two trucks used by Chicago has a radio telephone. No spare tires are carried for sanitation and highway equipment in any of the cities, except for very light equipment. Washington has been able to reduce tire replacements on its trucks by getting its paved alleys cleaned and by paving access roads to dumps.

Most of the cities visited are using procedures designed to keep the using service as well as the shop informed on the status of equipment requiring roadside repair work. Chicago has calls come simultaneously to the shop and central office.

To expedite repair, Detroit uses a system of numbering vehicles which identifies the year, make, and type of vehicle. A driver on calling the shop need simply give the vehicle number and approximate trouble, and the roadside repair mechanic can usually carry the right parts to the job.

In all cities visited, accident cases are processed on separate job orders, and complete data on repair costs are held for, or forwarded to, the city's legal department. A few cities are making new ef-

forts to reduce accidents. Detroit has a good device in its accident board, which fixes responsibility of city employes for accidents. Representatives from the police, law, motor transportation, and comptroller's departments and a union representative are on the board, whch meets once a week. Charges for accidents have been assessed in 50 per cent of the cases reviewed in the past year and the number of accidents has dropped.

Replacements, Additions, and Standardization

Every city visited has a great many old pieces of equipment and many pieces beyond a useful service life. Large numbers of replacements and additions are being obtained this year. Cities having revolving funds seem to be in the best position now to make replacements deferred by the war. Chicago, for example, is procuring 200 closed trucks for refuse collection alone, for replacements and additions.

None of the cities has a retirement program covering all mechanical equipment, but seven cities have (or will have at the end of 1947) programs for retirement of most of their vehicles.

Of the cities observed, only Cleveland, Pittsburgh, and Philadelphia, apparently, will be unable to replace sufficient vehicles in 1947 to bring the age of all equipment below a normal service life. For trucks, the service life most frequently used for estimating depreciation and anticipating replacement is eight years. Cities which rent equipment to using services all keep depreciation records. These are adjusted when major rehabilitation work is done.

All cities observed desire to standardize on their equipment for certain uses and for general purposes. Standardization of equipment by purposes is being approached in New York, Chicago, Pittsburgh, Washington, Minneapolis, and Newark. In general, the major difficulty encountered in standardization is the practice of awarding contracts for equipment to the lowest bidder under fairly wide specifications. The most common practices to bring about standardization are (1) closed specifications and (2) the purchase of a large quantity of vehicles for a single purpose in one year, and for a different purpose the next year, and so on.

Proposed Facilities and Methods

Five cities (Chicago, Philadelphia, Cleveland, St. Louis, and Washington), which either do not have major repair work in central repair shops or have inadequate shops, are planning new shops for central repair. Except in Philadelphia, these plans have been approved or scheduled by the respective city planning agencies. Pittsburgh is the only city contemplating a major reorganization of repair activities. There, a city-wide central repair organization under the present Superintendent of Automotive Equipment, who is now a coordinating officer, is being considered.

The above data, as well as additional information on the Philadelphia situation, and an appraisal and a discussion of recommended procedures, are contained in a 32-page booklet by Major Sawyer. Copies of the report may be obtained from the Bureau of Municipal Research of Philadelphia, 311 South Juniper St., Philadelphia 7, Pa.

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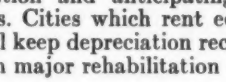

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Water Supply

Highways and Airports

This section digests and briefs the important articles appearing in the periodicals that reached this office prior to the 15th of the previous month. Appended are Bibliographies of the principal articles, in which the articles in each periodical are numbered consecutively throughout the year, beginning with our January issue.

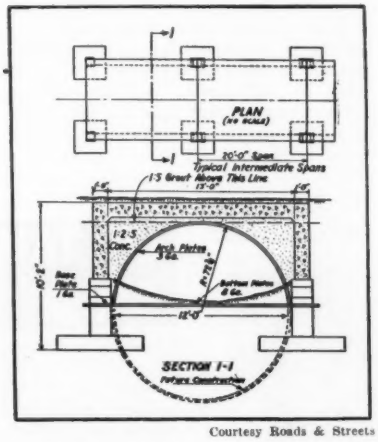
The letter and number at the end of each item refer to those used in the Bibliography. Numbers not found in the current Bibliography will be found in the one published the previous month.

The Highway and Airport Digest

Drainage at Mitchell Field

An outstanding feature of the enlargement of Mitchell Field, Milwaukee's airport, is the strengthening and lining of 1109 ft. of an existing covered drain which receives the flow from all underdrains and storm sewers of this saucer-shaped airport. This 12-yr.-old drain is rectangular, 12′ wide by 5.25′ high with a 12″ concrete slab roof designed for a 50,000 lb. plane load. To carry the new 150,000-lb. design load, an arch of Armco steel has been inserted, the haunches being filled with 1:2:5 concrete. This gives a semicircular drain, which can later be made full circular by excavating for and placing inverted arch liner plates.

The drains throughout are made of corrugated iron pipe, bituminous coated with paved inverts; 15″ to 43″ for storm drains, and 12″ underdrains parallel to each edge of runways and taxiways; all backfilled with gravel. Trenches for storm drains were excavated by dragline and those for underdrains by a trenching machine.[N21]



Courtesy Roads & Streets

Details of 1109-ft. tunnel lining using Armco plates.

Prequalification of Contractors in Connecticut

The State Highway Dept. of Connecticut receives no bids from contractors who have not filed annually an 8-page form properly filled out, giving the contractor's status and organization; financial statement; list of equipment owned, including capacity, condition, age, and cost; projects completed or incompleted; and employment record of the principal individuals of the company. The department keeps a record of the work each contractor has done for the State, its quality, and whether completed on, before or after the time limit. From this information they form an opinion as to the size and kind of job he is fitted to undertake, and ask his bids only on such jobs; offering, however, to discuss the matter with a bidder and his bondsman if he thinks he is being discriminated against. The idea is very acceptable to qualified contractors, bonding companies, and the Department.[N25]

Protecting Side Slopes

Stabilization of side slopes on California highways is meant to maintain the shape of the slope by holding soil in place and to provide a base or foundation for permanent landscaping. On slopes 2:1 or flatter, the plan adopted is to cover the slope with 6″ of top soil if it is available, otherwise to cultivate the slope 4″ to 6″ deep, applying fertilizer; spread straw and embed it into the soil with a sheepsfoot roller; and plant through the straw into the soil. If the slope is seeded, however, two-thirds of the seed is sown before application of the straw. The straw prevents the blowing or washing away of the soil and serves as a mulch. If the slope is steeper, up to 1½:1, the procedure is the same except that the roller is not used, but instead the straw is held by spreading wire 2″ or 4″ mesh over it and anchoring it with 2 x 2 x 18″ stakes spaced 3 ft. apart. In the case of slopes steeper than 1½:1, the slope is covered with wooden frames made of 2 x 4 lumber spaced 2 x 3 ft.; these being secured by stakes if the slope is over 15 ft. high, slope distance. The frames are filled with moist top soil, compacted, fertilizer is applied, and straw is spread over the slope. Wire mesh, 14 gauge 4″ mesh, is placed over this and wired to the frames. Ground cover plants are planted through the straw. The plants most commonly used are English ivy, honeysuckle, vinca and trailing lantana.[E7]

Effect of Petroleum Constituents on Road Tars

Differences in behavior, during construction, of road tars meeting the same specifications have been traced to the presence in the tars of petroleum-like constituents consisting of unsulfonatable hydrocarbons. In an investigation by Public Roads Administration it was found that the unsulfonatable hydrocarbons have a flocculating effect on the tar which increases as the percentage of unsulfonatable hydrocarbons increases until a separation of the blend into two phases results. The progressive flocculation up to the point of separation can be detected only by microscopic examination.

In the course of the investigation, a new test was devised to measure the relative compatibility of unsulfonatable hydrocarbons and tars. It involves adding increments of a petroleum distillate to the tar and noting the "separation point"—the percentage of diluent at which the blended materials separate into two phases. The test indicates the relative amount of unsulfonatable hydrocarbons in tars from the

same source, but cannot be used as an exact determination of these constituents in lieu of the sulfonation-index test. The new separation-point test will be useful as a rapid laboratory check on the uniformity of tar shipments from the same source.[U6]

Distribution of Highway Taxes

The large postwar highway programs, coupled with greatly increased construction costs, have intensified demands by both State and local groups for additional highway funds. In order to fill the more urgent needs, several States have been compelled to increase highway-user tax rates or to revise distribution formulas. This has brought about some misconceptions concerning the present allocation of these revenues. Actually, there does not appear to have been any significant change in the basic State—local distribution ratios in recent years. Both State and local roads have benefited from greater tax yields, with the State generally retaining the larger share of total revenue, for expenditures on State highway systems. Where revisions of the distribution formulas have occurred, increases in State or local shares have usually been accomplished by decreasing the portion of tax revenues formerly allocated to nonhighway purposes.

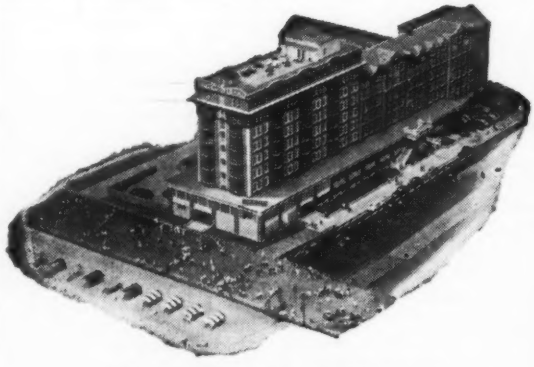
In 1940, 15 States used no highway revenues for non-highway purposes. In 1946, there were 22 such States and 7 others that diverted less than 1%.[U5]

Bituminous Concrete Replaces Sheet Asphalt

Until recently almost half of the 200 miles of streets in Hartford, Conn., were 3″ sheet asphalt on a concrete base, and all since 1916 had been laid by one contractor. To secure competition, in 1946 the city called for alternate bids on sheet asphalt and dense-graded bituminous concrete, and contracts for both kinds were awarded to three contractors. The bituminous concrete was laid by mechanical pavers, which give a smoother and better riding pavement than does hand raking of sheet asphalt, and it is laid much more quickly. It proved so satisfactory that in 1947 all paving was done with mechanical pavers. Some old sheet asphalt pavements have been covered with 2″ of bituminous concrete, in preparation for which 0.2 gal. of 120-150 penetration asphalt is applied to the old pavement and covered with about 25 lbs. of hot sand premixed with 2% of MC2, and immediately opened to traffic for several months, the pneumatic tires working this cover into all cracks and breaks in the old pavement. In other cases the old asphalt pavement is removed, the concrete base repaired, and 3″ of bituminous concrete laid in two courses.[P10]

Runways For 75-Ton Wheel Loads

At Patterson Field, near Osborn, Ohio, a runway 10,000 x 300 ft. and a taxiway 7,075 x 150 ft. were built to carry a gross plane load of 300,000 lb.; using five 34-E dual-drum pavers and about 100 other major units of power equipment and some 300 men. The runway is 21″ thick and the taxiway 25″, of portland cement concrete, reinforced for temperature with welded wire fabric, with transverse contraction joints spaced 28 ft. apart. The pavements were laid in 25 ft. lanes, the 21″ at the rate of about 2,500 lin. ft. in a 16-hr. day, with a maximum of 3,192 ft. Two of the pavers worked in tandem beside the lane being placed, and three were operated as a central mixing plant. The trucked concrete was dumped just ahead of the front paver, immediately behind which was a concrete spreader which struck off the concrete 4″ below the top of the pavement, using 6 electric vibrators. On this was placed the reinforcement, on which the second paver placed the top 4″. Behind it were two finishing machines, a longitudinal screed, jointing and finishing crews, and a rig for applying a membranous curing compound. The final finish was by burlap drag and long-handle wooden floats. Concrete was dumped on the subgrade from a bridge rolling on rubber rollers riding on the edge of the adja-



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cent lane and steel wheels riding on steel forms.

The subgrade was prepared by removing 1 to 5 ft. of unsatisfactory material and replacing it with selected material compacted with sheepsfoot rollers. This was smooth-graded with two motor patrols, and a scraper, followed by two 3-wheel rollers. A form grader cut trenches for the forms, which were placed with front-end-lift tractors. Then the subgrade was finished with a motor patrol grader followed by a subgrade planer and rolling with a 5-ton 3-wheel roller.[E9]

Willow Mats For Bank Protection

For protecting banks subject to erosion by streams, Ohio Dept. of Highways has devised a system employing live willow and other live tree branches, tied down with fence wire. After the slope has been smoothed, branches are laid on it with the butts at the bottom resting in a trench 2 ft. deep and afterward backfilled; the side branches making a mat not less than 8" thick near the toe of the slope and 2" at the top; the space between butt ends not exceeding 4". On this is laid a wire fence, and forked willow branches are driven perpendicular to the slope to a depth of 2 ft. to hold it in place. Cement bags filled with Class C concrete are placed near the bottom at 7½ ft. intervals and held there by stakes and wires to weight down the mat. The branches are cut not more than 24 hr. before being placed and soon take root and form a dense growth, protecting the soil from erosion.[N26]

Traffic on Rural Roads

Total rural-road traffic in 1946, the first full post-war year, broke all previous records. The sharp rise in use of heavier commercial vehicles that occurred during the war was undiminished. Truck-combination travel was 27% higher than in 1941. Axle loads were 31% heavier than in the prewar period, and the frequency of heavy axle loads was 5 times greater. Especially notable was the great postwar increase in traffic in the West, particularly in the Pacific States. In the eastern portion of the country, especially the New England States, the traffic has remained generally below the 1941 figures.[U3]

Street Maps For Small Towns

A reasonably accurate street map of a town or small city can be made from a topographic map of the U. S. Geological Survey as a basis, or better still from a photographic copy of the original drawings from which the Survey prepares such maps and which are at a larger scale. The topographic maps are on sale throughout the country. The photographic copies of many areas are obtainable from the Map Information Office, U. S. Geological Survey, Washington, D. C. Enlargements of the desired area are then made photographically to the scale chosen, usually 500, 800 or 1,000 ft. to the inch. This is traced, omitting contours and other features not desired and adding changes made since the original map was drawn; street names are lettered in, and names of prominent buildings if desired. Instead of a Geological Survey map, an aerial photograph can be used; but there may be considerable scale error if the land is not flat, unless the map has been adjusted to horizontal control by a skilled photo-grammetrist. Aerial photographs of many regions are obtainable from the U. S. Geological Survey.[E8]

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8. Street Maps for Small Towns. By Lester F. Dingman. Pp. 68-70.
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Getting a Needed Paving Job Done

ARTHUR E. J. JOHNSON
City Manager and City Engineer, Shenandoah, Iowa

EARLY in 1946, I was selected as the first City Manager of Shenandoah, Iowa, after serving as City Manager at Red Oak, Iowa, from 1934 to 1943, and at Clarinda, Iowa, beginning in 1943—the second City Manager at Red Oak and the seventh at Clarinda.

When I came to Shenandoah, the City Council had a paving program totalling about $350,000 which was intended to make the streets passable. Most of the streets were in very bad condition; it was impossible to drive down some of them without running into holes from one to four inches deep, which was very hard on tires. The resolutions of necessity and advertisement for bids had been published, the job was ready for bids, and the citizens were clamoring for good-riding streets. We waited for the letting, and when the bids were received and tabulated the costs were 23% above estimates and had to be rejected.

This left us where we were when I arrived. My suggestion to the City Council was to circumvent the antedated legal resolutions of necessity and other red tape of the Iowa Special Assessment laws and get the people who were concerned to waive the legal procedure and have the streets repaired without the necessary publications and payment delays.

My proposal was that we get a petition signed by 100% of the owners, to waive the legal procedure and agree to pay the cost of construction. The City Council was dubious —they said we could not get 100% of the people to agree to work together for any street to be resurfaced; but they agreed to let us try, and by the time of the next council meeting 66 of the 67 property owners had signed the papers that were prepared and were approved by our City Attorney. Several of the property owners agreed to take up a collection to pay for the assessment owed by the 67th property owner, and the City Council voted to let us go ahead with the program on our first street—8th Avenue—which is about one-half mile long.

This started the work and since then about 100 blocks have been either surfaced or re-surfaced with asphalt and special small limestone rock and/or sand and gravel. Incidentally, the 67th property owner was the first *man* in to pay his assessment—there were two women in before him to pay their assessments, but he was the first *man*.

Anywhere, things can be accomplished by people working together, and I believe anywhere in the U.S.A. we can accomplish our aims such as better streets, better schools, and utilities, if only we can get the confidence of our neighbors and treat that confidence honestly; give them the things they want, and they will pay for them without quibbling and our communities will advance steadily and permanently.

Doing the Work of Paving

Elmer Gee, the head of one of our local contracting firms, saw the potentialities of the move and agreed to take on the work. This consisted

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of an inverted penetration method of surfacing, with an armor coat of asphalt and mineral aggregate about ¾" average thickness. We put on a prime coat of SC-1 or SC-2 asphalt and when this became tacky followed it with from 0.25 to 0.35 gal. of SC or MC-3 asphalt to the square yard and covered with crushed limestone passing a ⅜" screen and retained on a ⅛" screen. This was broom dragged and rolled to an approximate smooth surface; then a second coat of asphalt was applied at the rate of 0.33 gal. per sq. yd. with cover of mineral aggregate approximating 30 lbs. per sq. yd., applied with a gravel spreader. This was broom-dragged and rolled with a rubber-tired roller; traffic was halted only between the application of the prime coat and the first application of mineral material.

We would be pleased to have you all ride over the streets today and see the improvement accomplished in one short year. All of you can do it if your folks believe in your Administration.

This job cost only 10% of the original estimate; if the job lasted only four years it would be far better than the original; so far some of it is about 2 years old now and looks good for several more; just like some of the roofing and paint ads "if you preserve the surface, you preserve all—do not let your foundation weaken." Our whole idea was to save the foundation which all of our people who are adjacent to the project paid for. Modern traffic with its heavy loads has made necessary the slogan "Save the surface, and save the whole paving job."

C.A.A. Sets Runway Standards

The Civil Aeronautics Administration has established maximums on length, width, and strength of runways for airports for which federal funds will be supplied.

The standards below, as summarized by the American Public Works Assn., are for airports at sea level and a temperature of 59 degrees F. The lengths will be increased 7 per cent for each 1,000 feet of elevation above sea level, and one-half of one per cent for each degree by which the mean temperature of the hottest month of the year, averaged for a period of years, exceeds the standard temperature. Gradient will also be taken into account in determining length.

Air Line Service	Runway Length Feet	Runway Width Feet	Taxiway Ldg. St. Width Feet	Taxiway Ldg. St. Width Feet
Feeder	3500	100	40	300
Local	4200	150	50	400
Express	5000	150	60	500
De Luxe	5900	150	75	500
Int'l	7000	200	75	500
Int'l Exp.	8400	200	100	500

Air Line Service	Pavement Loading—Lbs. Single Wheel	Dual Wheel
Feeder	15,000	20,000
Local	30,000	40,000
Express	45,000	60,000
De Luxe	60,000	80,000
Int'l	75,000	100,000
Int'l Exp.	100,000	125,000

Melting Snow at the Chicago Airport

The first snow-melting system to be installed at an airport is believed to be at the American Airlines hangar entryway at the Chicago airport. A system of wrought iron pipe was embedded in the pavement beneath the doors of the hangar and hot water, with anti-freeze added, is circulated through them to keep the surface temperature above freezing. The strip heated is 7 ft. wide and 514 ft. long. About 2 miles of 2-inch and 2½-inch pipe were required. During the heating season, the water is reused, as in any hot-water heating system but in the spring it may be drained out.

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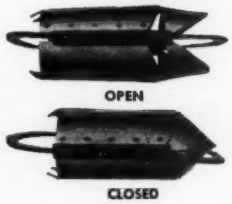


Town and City officials throughout America are adopting OK CHAMPION Power Sewer Cleaner to keep sewers clean and efficient. Takes roots, dirt, sand, and other debris up from main in one continuous operation. All men work above street level.

Pulling forward opens the jaws that bite into obstructions. Reversing the pull on the bucket automatically closes jaws which hold load pulled back to street level. Write for complete details.

CHAMPION CORPORATION 4716 SHEFFIELD HAMMOND, IND.

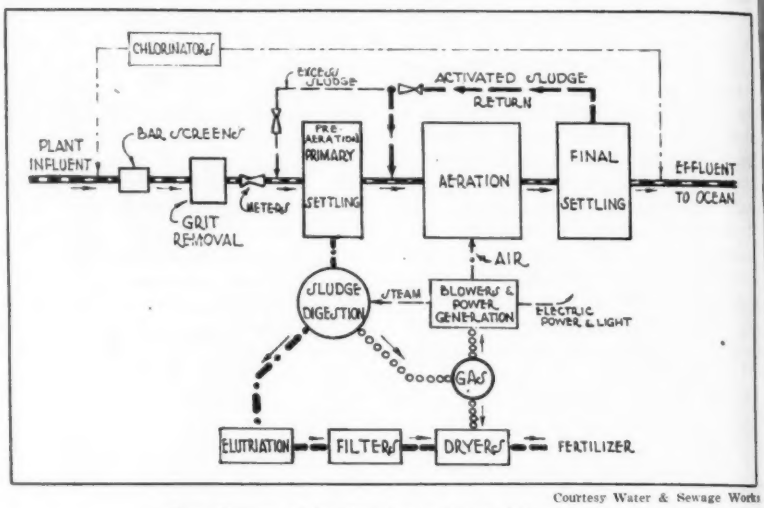
The Sewerage Digest

Metering at the Hyperion Activated Sludge Plant

Los Angeles, Calif., is constructing a high-rate activated sludge plant with a capacity of 245 mgd, which will comprise coarse screening, grit removal, main sewage flow meters, pre-aeration, primary sedimentation, return sludge, primary effluent mixing, aeration, final sedimentation and effluent into the ocean. The excess sludge and primary sludge will be digested, elutriated, and filtered on vacuum filters, and dried to 10% moisture for use as a soil conditioner.

The main sewage meters are two 108" x 54" Venturi meters. Return activated sludge will be metered by two 60" x 30" Venturi meters, and excess activated sludge also will be metered. Main air consumption will be metered through two 66" Venturi meters, and the headers to each pair of tanks will be metered.

There are 18 digestion tanks in three batteries, each battery containing 4 primary and 2 secondary units; and the sludge will be delivered to them by 4 pumping stations. The problem is to divide the flow in proper ratio. Each battery of digesters will have a separate Venturi body and control valve. The meter handling the largest flow or the meter in the line with the greatest friction loss will be set as a master controller and the ratio of desired flow to the remaining batteries will be set on the other instruments. The control will be maintained in the control center for so-called battery "A"; however, each battery will have flow recorders so that an operator at any battery will be aware of flow condition existing in the battery. Sludge flow to the primary tanks will be controlled by remote control valves at a panel in each battery. Valve setting will be recorded on the flow chart with the flow in each battery so that the actual quantity of sludge fed to any tank can be determined by recording integrators as valve settings are changed. Sludge flow will be from the primary digesters to the secondaries by displacement or by pumping.[G12]



Courtesy Water & Sewage Works

Flow diagram of the Hyperion activated sludge plant.

Sewage Treatment At Military Installations

• The article published under this title is the concluding chapter of the comprehensive report of the Subcommittee on Sewage Treatment, National Research Council, published in Sewage Works Journal for September 1946 and abstracted in PUBLIC WORKS shortly thereafter. It is a summary and an abstract of the most significant findings and the conclusions drawn from such findings; applying to military installations directly, but many of them applicable to non-military ones. The committee recommended that "The design of sewage treatment works for military camps should be handled only by competent firms of sanitary engineers, whose competency should be certified by the design divisions of the Department of Defense. . . . Patented or proprietary processes of sewage treatment should not be designed unless such processes have been operated and proved efficient in treatment of army camp sewage. The Subcommittee deplores the loss of good civilian sewage works operators and chemists in World War II by induction into the army and removal from operation of sewage treatment works. . . . When inducted men with sanitary engineering or chemical skill are assigned to sewage works operation, only the most urgent manpower needs should be allowed to result in their transfer."

The different types of equipment used and the satisfactoriness of their operation at the army camp are discussed at some length. Comminutors were installed at most of the camps and performed an "especially valuable service" to the nearly universal satisfaction of the operators. The performance of the sedimentation tanks was distinctly inferior to that obtained in municipal service, chiefly because of the non-uniformity of flow of sewage due to the regimented mode of life inherent in military training, and to pulsating flow caused by improper pump sizes and float switch adjustment. About fifty contact aeration plants were installed at army camps. Under favorable conditions good effluents were obtained, but when strong stale sewage had to be treated or difficulties developed in the aeration system, effluents were unsatisfactory and odors intense; and this type is less desirable for use in military camps than are trickling filters." Activated sludge plants, as designed at present, "are not sufficiently flexible to handle the variations in flow and load that are expected in military posts." Oxidation ponds were used for secondary treatment at a number of camps. They "had a remarkable ability to remove coliform organisms," and caused no mosquito nuisance.[C17]

Step Aeration Of Activated Sludge

"Step" aeration is defined as "the introduction of sewage in controlled amounts at multiple points along the flow of returned activated solids through the aeration tank." A 7-month trial of it at New York's Bowery Bay plant showed that B.O.D. can be reduced 90 percent in the secondary system when the loading is two to three times greater than that normally handled by the conventional activated-sludge process.

Three control criteria were used. The most important is sludge "age" defined as "the average number of days suspended solids remain under air from the time they first enter the secondary system until they leave." The 30-min. cylinder settling test was used for the second control, to maintain settling values of the aerator effluent at 20% or less and particularly to avoid wide fluctuations of this measurement.

The third control consisted of alteration of the method of adding primary effluent to the aerator, to either the 2nd and 3rd or 3rd and 4th passes. This furnished highly flexible treatment in adjusting to loads. The least possible quantity of activated solids should be passed to the final tanks, regardless of their settling qualities, while maintaining adequate sludge aid; which criterion is satisfied by this method.[E13]

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Control of Sulfide in Sewers

In southern California the deterioration of sewers due to sulfide is of general concern. It seems to have been demonstrated that the sulfides are developed in deposits on the walls of sewers and that the only satisfactory solution is to prevent the accumulation of such deposits. Long Beach has had excellent results from the use of a beach ball dragged through the sewer. To prevent cuts in the balls, they were wrapped with burlap or enclosed in canvas bags. A member of the department has developed a ball surrounded by diagonal ribs that act as squeegees. (Described in the *Sewerage Manual.)*

To maintain the dissolved sulfides in the sewage below 0.5 ppm, chlorine was applied to the sewers at dosages as high as 12 to 15 ppm, costing an average of $12 a day. Later, Cloroben was substituted with a very substantial saving in cost. To obtain good results, a contact period of 2½ to 3 hr. seems to be necessary.

In the Orange County (Calif.) joint outfall sewer, trial has been made of chlorine, ozone, ferrous sulfate, lime, ferrous chloride, zinc sulfate, Cloroben, compressed air, tri-chloro-phenol and sodium nitrate. At present, chlorine and/or lime is used for controlling sulfides in gravity sewers, and compressed air in force mains. In the compressed air method an 80 cfm compressor was connected to a 16" force main 2 miles long. At first the sulfides rose from 7 ppm to 18 ppm, due to the slimes being blown loose from the pipe; but after the first day the sulfides were reduced to zero while traveling the two miles in the main.[C19]

Equipment For Trenching

Under present-day labor and wage conditions, most trenching can be done much more cheaply and rapidly by mechanical equipment than by pick and shovel. Ditchers of both the wheel type and boom type are made by several manufacturers. Models of the wheel type are furnished to cut trenches 11" to 30" wide and to a depth of 5'6". Boom type machines cut trenches 16" to 84" wide and to depths as great as 24", although limits of 8' to 12' depth are most common. Most of these are equipped with devices to prevent their damaging pipes or other underground structures. Records of trenching 6' to 8' deep at 50 to 300 lineal feet an hour are reported.

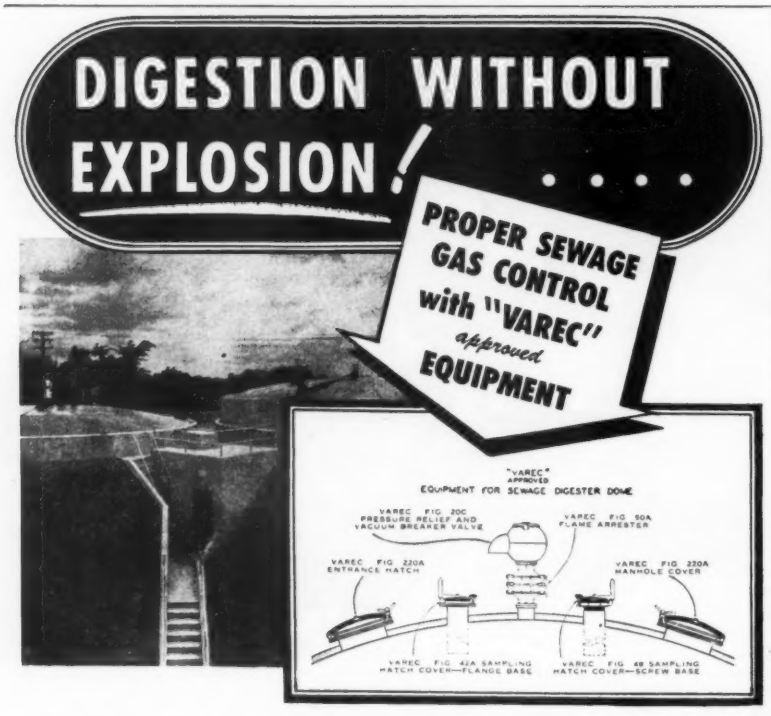
Power shovels used as trench hoes are used for trenches 24" to 40" wide or more and depths up to 15 ft. An advantage of these is that they can be used to handle heavy pipe into the trench. Under good conditions they should dig more than 500 ft. of trench per day. They probably are less adaptable to digging where there are pipes or other structures that might be damaged.[P13]

Preaeration For Treatability

In true preaeration, sufficient oxygen is added to the sewage to permit a sample to show at least 0.2 ppm of DO upon standing in a DO bottle (submerged) for 60 min. Such preaeration applied to domestic sewage of any degree of septicity will satisfy the chemical avidity of raw sewage for dissolved oxygen, will eliminate all hydrogen sulfide odors, and will cause the release of entrained gases of partial decomposition. It will stop putrefaction in primary settling tanks and thus eliminate further generation of gases which buoy up sewage particles and thereby reduce primary sedimentation efficiencies. By increasing the treatability of the sewage, preaeration makes possible a reduction in secondary treatment capacity and in aeration and recirculation power requirements.[C20]

Effect of Ground Garbage in Sewage

Adding all of a community's garbage, ground, would increase the volume of sewage by not over 2%. It would cause no trouble in the sewers if they are well designed. It would increase the oxygen demand by about 30% and the suspended solids by 50 to 100%. The digester capacity should be increased 60 to 100% and the gas produced will be increased at least in the same proportion. The cost of handling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PROPER SEWAGE GAS CONTROL with "VAREC" approved EQUIPMENT
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VAREC FIG. 20C PRESSURE RELIEF AND VACUUM BREAKER VALVE
VAREC FIG. 50A FLAME ARRESTER
VAREC FIG. 220A ENTRANCE HATCH
VAREC FIG. 220A MANHOLE COVER
VAREC FIG. 42A SAMPLING HATCH COVER—FLANGE BASE
VAREC FIG. 48 SAMPLING HATCH COVER—SCREW BASE

Gas given off during digestion is generally 60 to 78% methane, which is explosive when mixed with between 8 to 19 times its volume of air. Hydrogen Sulphide is usually present in sufficient quantities to cause greater hazards. Explosive mixtures in the tops of sewage digesters can and have resulted in dangerous explosions. But if proper precautions in handling these gases are observed there need be no hazard about digestion plants.

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The Daily Argus

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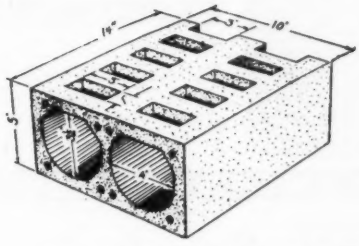

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garbage in this way varies from $0.70 to $1.20 per ton, discounting possible salvage from using gas. Cost of handling other refuse would be reduced, for collections could then be made only once a week.[J6]

Brass, Electroplating And Textile Wastes

Brass, copper and electroplating wastes contain no bacterial food, require no oxygen, are toxic and inhibit bacterial growth and decomposition in a receiving stream. The treatment of them is essentially a neutralization and precipitation process. In neutralizing with lime in a pilot plant, the lime dose was automatically controlled by a pH recorder and a pH of about 80 was maintained; and the best clarification was obtained by flowing directly from the flash mixer to the clarifier without flocculation. An ion-exchange process was tried but with less favorable results. Studies of the recovery of copper, zinc and chromium indicated the possibility of this "at a cost whereby the net value will pay for a portion of the treatment cost."

Electroplating wastes are treated in Connecticut by either chemical precipitation or lagooning. Disposal of the sludge is a problem, a promising solution of which is dewatering on a vacuum filter.

Textile wastes are usually treated by chemical precipitation, the chemicals used including sulfuric acid, ferrous sulfate, alum, lime and calcium chloride.[C18]

New 72-inch Concrete Ocean Outfall

About 4,000 ft. of 72" reinforced concrete pipe recently was laid in the ocean bed as an outfall for the Los Angeles Sanitation Districts, paralleling a 60" line laid about 10 yr. ago. The latter has proven very satisfactory, and the new line was made similar to it in most respects, the differences being chiefly the omission of some of the precautions taken with the old line which experience indicated to have been unnecessary. In the old line, ball-and-socket type joints were used at 24 ft. intervals; but a careful study of the existing line indicated that they were unnecessary and they were omitted in the new one. In the old line, manholes had been spaced 187 ft. apart, but 432 ft. in the new one. Lengths of pipe in the old line were 12 and 18 ft., but the new one was made in 24 ft. lengths —believed to be near the record length for precast, poured-on-end reinforced concrete pipe.[E14]

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15. Maine River to Be Freed of Pulp and Paper Mill Wastes. Pp. 70-71.
16. Overhauling and Improvements Better Buffalo Plant Operation. By John W. Johnson and George F. Flynn. Pp. 72-73.
17. Experiences in Disposing of Chemical-Aeration Sludge. P. 74.

I *Municipal Engineering (England)*
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7. Improved Methods of Refuse Collection and Disposal. By W. E. Pierce. Pp. 100-102.

P *Public Works*
March

12. Small Sewage Treatment Plants: Primary Settling. Pp. 24-26, 30.
13. Trenching Equipment. Pp. 34-35.
14. Special Wings on Bulldozers Help in Sanitary Fill Operation. Pp. 40, 52.

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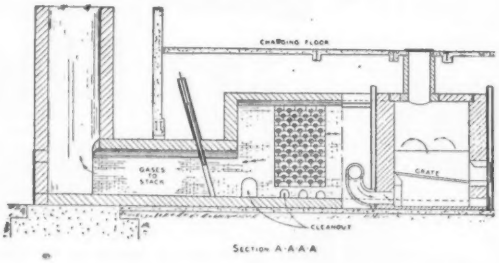

SECTION A-A-A-A

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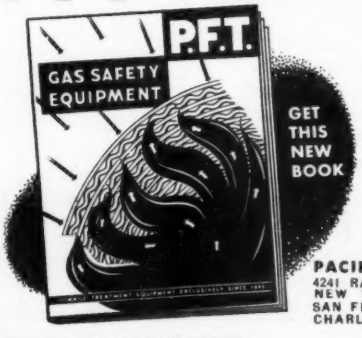

New Bulletin 221 describes the recent improvements in P.F.T. Gas Safety Equipment; for better protection for boiler rooms and other installations, and longer service life for the equipments.

All units are illustrated with detailed drawings. Specifications, typical gas piping arrangements and charts for selecting sizes are included.

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Who Designs Water Works Structures?

In a recent questionnaire sent to water works superintendents, the question was asked: "Who prepares plans for increased water supply developments?" and spaces were left to indicate whether this was done by the city engineer, the water department, or consulting engineers.

Of the replies, 260 showed that design was the responsibility of the city engineer; 315 said that design was done by the water department; and 294 stated that they employed consulting engineers for such work. In most cases the name of the consultant was given, and in about 10% of the cases, design responsibility was a function of two or more of the above.

Heated Truck Bodies Proposed for Snow Removal Work

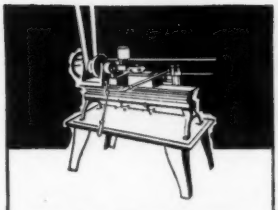
The City of Portland, Maine, is exploring the possibility of using heated truck bodies for snow removal operations, according to the American Public Works Association. The scheme calls for the reduction of snow to water in heated trucks which could then be emptied into nearby sewer openings, thus avoiding long and costly hauls to snow dumping points and reducing the number of trucks needed for snow removal work. L. S. Moore is City Manager of Portland.

Radio for Snow Plows Increases Efficiency

Two-way FM radio has increased the effectiveness of snow plows in Onondaga County, N. Y. Another innovation has been the use of a 10-ton "tank retriever" wrecker, also using radio, which keeps the three heavy radio-equipped plows in nearly full-time operation. These plows are truck-mounted, V-type. Using these plows in conjunction with the wrecker and the foremen's cars, also radio-equipped, it has been possible to handle snow plowing problems with less than half of the equipment normally required, according to Ray B. Traver, County Superintendent of Highways.

This installation operates on the highway maintenance radio channel of 37.98 megacycles and covers 1,050 sq. miles of the county.

A 250-watt transmitter at an elevation of 1,600 ft. is remotely controlled over a single-pair telephone line from the shops at Jamesville, 3½ miles away. The installation was made by General Electric.



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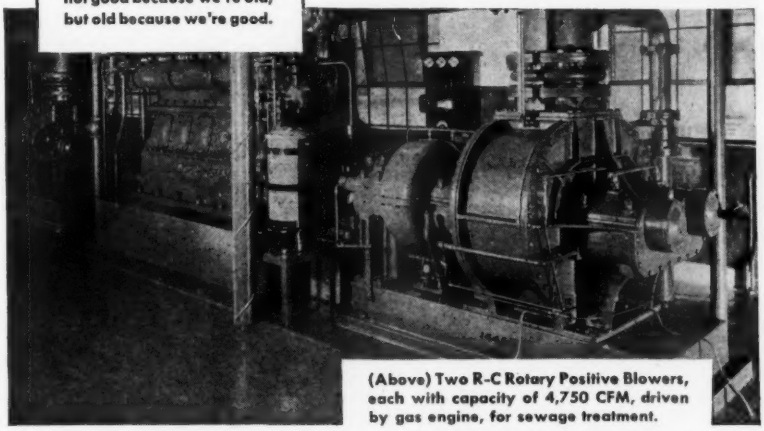
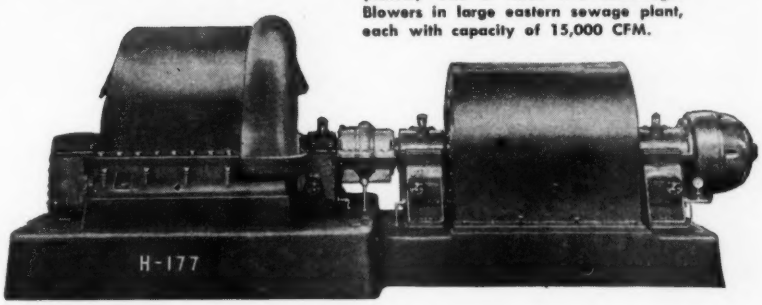


(Above) Two R-C Rotary Positive Blowers, each with capacity of 4,750 CFM, driven by gas engine, for sewage treatment.

(Below) One of three R-C Centrifugal Blowers in large eastern sewage plant, each with capacity of 15,000 CFM.



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The Water Works Digest

Taste and Odor Control at Philadelphia

In treating the river supplies of Philadelphia, Pa., the use of carbon has been very successful in removal of the phenolic-like tastes caused by a variety of wastes. Previous to the adoption of carbon treatment, chlorination produced objectionable tastes of this type; but carbon prevents this although chlorine dosages have been much increased. At the Belmont plant the detention priod is so short that it has been impossible to control and treat by chlorinating to the break-point. Here ozone will be used for oxidation and will destroy the oxidizable materials in the few minutes of retention in contact tanks. Ozone, however, will not produce any permanence of sterilizing residual and ozonized water will need to be post-chlorinated. The Belmont ozonation plant now under construction is said to be the largest ozone-generating plant in the world.[X12]

Economy in Use of Mechanical Equipment

In laying pipe in 1947, the Augusta, Me., Water District effected considerable economy by using a ladder-type trencher for excavating trenches, and a small crawler-type tractor with a ¾-yd. front-end bucket for backfilling, removing rocks from the trench, transporting pipe and placing it in the trench, rolling the backfill, and handling hydrants and gate valves. The trencher dug trench 5½ to 6½ ft. deep in very hard, compact clay at the rate of 117 ft. per hour, reaching a maximum of 5½ ft. a minute. The tractor backfilled at an average rate of 53 ft. an hour. Although material costs have increased about 50% since 1941 and labor wages at least 100%, the unit cost of this work in 1947 was very little greater than in 1941.[V1]

Demand Costs In Water Rates

The author suggests that, in preparing a water rate structure, the costs be divided into three groups: Customer costs, incurred irrespective of the quantity or rate of use of water; demand costs, which are primarily fixed charges on the size of the plant needed to meet peak requirements; and output or operating costs. The principal objections offered to the use of demand charges are practical difficulties in measuring the demand, and public resistance. No demand meters for water are now available, but the general principle embodied in demand meters used by electrical industries could be applied to water meters and it is believed that makers of water meters would furnish them at reasonable prices if there were any demand for them. For 2" to 4" meters, a device could be applied similar to an automobile speedometer in principle except that the indicating pointer will remain at its highest position until manually reset.[X12]

Sedimentation in Purification Plants

Experiments on the upflow through a suspension of graded sand indicate that, for a suspension composed of uniformly settling particles, the concentration will be uniform where the upflow is in a cylinder. In an expanding cone the concentration will increase upwards. In a cylinder with graded particles the faster settling particles will be at the bottom and the concentration will be greatest there. In an expanding cone, the faster settling particles will also remain near the bottom, but the suspension will tend to be of a somewhat more uniform concentration in a cone than in a cylinder. In other words, relatively high concentrations will not be obtained at the bottom of a conical section.

The settling rate of a suspension or of an individual particle determines the maximum upflow rate that the suspension or particle can stand without being carried up with the moving water. In softening and clarifying units of the sludge blanket type, the settling rate of the sludge suspension itself determines what rate of rise the unit can withstand.

In units in which the treated water rises more or less vertically from a sludge blanket or slurry pool, the location, form and number of take-off points is quite important and should be given careful consideration. It is decidedly of advantage to have the clear water escape uniformly from over the entire slurry area.

In the case of large circular clarifiers with peripheral take-off, the depth from take-off to sludge level should not be less than about 1/7 of the diameter of the clarifier; if this is not possible, additional take-offs should be provided.[A18]

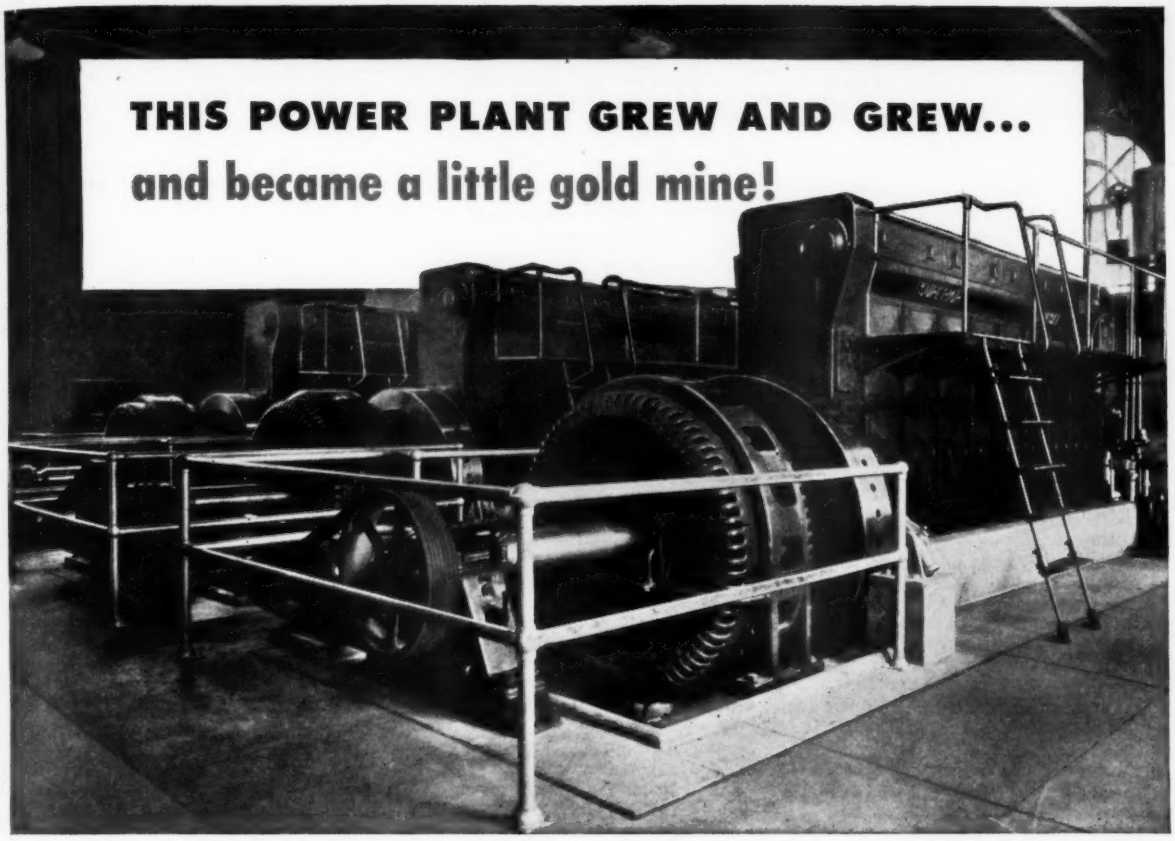
Public Service Commission And Water Works

This paper describes the extent to which the Wisconsin Public Service Commission controls the vital features in the operation of a utility and the manner in which the commission cooperates with the local municipal utility in giving better service to customers. The public service commission must hold a formal hearing to approve all extensions of the distribution system, as well as any new plant development, over a certain amount. It prescribes a uniform system of accounting which must be followed by all utility commissions. The public service commission is the final authority on rates and charges unless the utility takes its case to court.[A19]

Combined Spring And Surface Supply

Johnson City, Tenn., for many years obtained from springs and underground collecting fields a water with a hardness of only 30-32 ppm., clear and palatable, which flows by gravity to collecting reservoirs through about twelve miles of 16" c. i. pipe, which has a capacity of 5.2 mgd. After 35 yr. of operation this pipe has a Williams & Hazen coefficient of 140. The underground supply reaches a maximum of 4.8 mgd. in late winter and early spring and 3.2 during the sum-

Airplane spraying DDT emulsion for mosquito control. For details of the effects of DDT on fish and animals see our January issue, page 46. This photo courtesy of Communicable Disease Center, USPHS.



● In 1939 an Arkansas town plunged itself into a $240,000 debt to build a central power plant equipped with three, 8 cylinder 620 hp. Superior Diesels.

This plant proved to be a gold mine.

The demand for electrical power increased so rapidly that during the first five years the plant paid off the debt—provided free street lighting—cut consumer rates—and created a cash reserve! As a result of this performance, two additional 1200 hp. Superior Diesel Engines have been added to increase the plant's capacity.

Hundreds of other communities throughout the country are benefiting by the dependability and economy provided by Superior Diesels. These big, husky engines are used for water supply systems, sewage disposal plants, airport lighting and for many other vital services.

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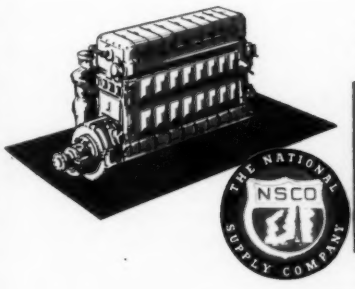

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mer. In July 1947 the maximum daily requirements ranged from 4.5 to 4.9 mgd. To supplement this supply the city in 1945 built a filter plant with 2 mgd capacity near the 16" main, which treats water drawn from a creek 500 ft. distant. A bypass loop connected to the 16" main receives filtered water pumped into it, with valves permitting flow to the reservoirs of underground water only, or this supplemented with filtered water. Chlorine can be applied to the former; but when combined supply is used it is applied to the filtered water only, but in such amount as to obtain the desired residual in the mixed supply. Should the demand exceed the gravity capacity of the 16" line, this can be increased by installing booster pumps along the line.[F9]

Main Disinfection

A "Procedure for Disinfecting Water Mains" was approved by the directors of the American Water Works Ass'n Sept. 30th, 1947, and is published in the Feb. 1948 Journal. It states that contamination of the inside of the pipe after it leaves the foundry should be prevented by sealing it, immediately after dipping, with metallic thimbles or membranes. Attempting to disinfect the pipe line after completion by flushing, though worth while, cannot alone be relied on to insure delivery of safe water. Depositing dry hypochlorite in each pipe as laid is ineffective. For packing joints, the materials recommended in order of precedence are (1) rubber rings; (2) asbestos rope; (3) treated paper rope; (4) braided cotton; (5) hemp, the least desirable, to be used only if treated with "Klerol" or "Polymine D." The committee recommends the following procedure where practicable:

By the combination of rate of flow and rate of chlorine application to the water entering the mains being treated, maintain a free available chlorine residual (*not* combined available chlorine) between 0.5 and 1.0 ppm. continuously at the most distant point or points. This condition should be maintained for a considerable period, probably about a month. After resuming normal operation, samples should be examined frequently for a week or ten days.[A20]

Disinfecting Large Reservoirs

Floods in Iowa in June 1947 contaminated many municipal water supplies, including distribution systems and reservoirs. The author discussed the measures taken (with remarkable success) for minimizing resulting hazards to public health. Concerning reservoirs he said:

"The distinfection of large storage reservoirs by filling them completely with chlorinated water may be impractical or impossible. The inner surfaces may be disinfected, however, by thoroughly spraying or washing them with a strong chlorine solution. Disinfection of the bottom of the reservoir may be facilitated by closing the outlet valve and permitting the chlorine solution to spread over the bottom surface. Smaller storage reservoirs can be disinfected by filling them with water containing 50 ppm. of chlorine and permitting a contact period of 4-24 hours." [A22]

Hydropneumatic Water Supply Installations

For providing water under adequate pressure to a small area where this can not be effected by gravity, there are two alternatives—an elevated tank or a hydropneumatic plant. The latter is usually the more economical for a relatively small area. Its main features are a closed steel tank, pump, air compressor, pressure switch control, and the inlet and outlet piping. The pump is usually an electric motor-driven centrifugal or plunger pump of sufficient capacity to maintain not less than the minimum pressure during the period of maximum demand. If the tank is protected against temperature variations, a compressor with a capacity of 2 cu. ft. of free air per minute is ample for large installations.

Before designing a plant, a thorough analysis should be made of the water demand to be provided for. In a properly designed tank the volume of air is many times that of water. The size of the tank depends upon the desired maximum and minimum pressures and upon the maximum rate of demand; which latter also determines the pump capacity.[A23]

Sodium Fluoride In a Municipal Supply

Sheboygan, Wis., after a publicity program, directed its Department of Public Health to have the water department introduce approximately one part of fluorine to every million parts of water distributed to the city. The application was started Feb. 25, 1946, and continued to date. No objections have been received from consumers. White sodium fluoride is used, a free-flowing powder that does not cake, costing about $2.20 per million gallons of water, or about 10 ct. per capita per year. The equipment and installation cost approximately $1500.

The fluoride is fed by a gravimetric feeder whose maximum capacity is 1 ppm. for the 18 gpd. maximum capacity of the plant, or 2.1 ppm. for the present minimum consumption. The application has ranged between 0.94 and 1.02 ppm. of fluoride. The untreated water contains 0.14 to 0.16 ppm. There would be an appreciable loss of fluoride if fed before or with the alum, and it is applied to the filter effluent. After feeding was begun it was five days before it reached the outer ends of the 126 miles of the distribution system.[G12]

Studying Well Water by Means of Conductance Equipment

The greatest aid to studying the quality of the water produced from different strata is conductance equipment. The specific electrical conductance of water is due to the ability of the minerals dissolved therein to carry electric current. As the conductance increases, each of the major constituents will usually increase also. The conductance equipment used by the California Water Service Co. consists of a cell about ⅞ in. by 8 in., about 1,000 ft. of cable, and a Wheatstone bridge.

The procedure used is first to measure the conductance of the water at the pump discharge. The cell is then lowered until it is opposite the pump suction. If the conductance is not the same as the water at the pump discharge, it shows that the cell constant has been changed. Twelve volts, D.C., from a copper oxide rectifier is impressed upon the electrodes for about one minute, and the polarity is reversed after about 30 seconds. The conductance is again measured. If the conductance is not equal to that of the pump discharge the process is repeated until it is, or until it becomes constant. The cell is then lowered down the well and readings taken in the usual manner.[G14]

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February 13

1. Water Supply in 1947. Pp. 93-94.

F *Water Works Engineering*
February

16. Distribution Practices at Mount Vernon, N. Y. By Malcolm Merritt, Jr. Pp. 122-126, 148.
17. Elevated Storage. By Angus D. Henderson. Pp. 136-137, 161.
18. San Diego, Calif., Obtains Supply From Colorado River. Pp. 140, 170.
19. Unusual Local Storm in Ohio Results in High Flood Flows. P. 141.

G *Water and Sewage Works*
February

12. Some Practical Aspects of the Addition of Sodium Fluoride to a Municipal Water Supply. By Jerome C. Zufelt. Pp. 57-60.
13. Hydrant and Valve Maintenance. By J. G. Carnes, Jr. Pp. 67-68.
14. Chemical Quality of Underground Water Supplies. By J. R. Rossum. Pp. 69-71.

P *Public Works*
March

8. Chicago's New Filtration Plant. Pp 21-23.
9. New Filters Supplement Spring Supply. By R. F. Taylor. Pp. 37-38.

X *Southwest Water Works Journal*
February

12. Standby and Ready-to-Serve Charges for Water Service. By David Pfeiffer. Pp. 17-19, 26.

Z *La Technique de l'Eau (Belgium)*
January

4. La Normalisation et l'Interpretation des Analyses d'Eaux. By R. Buydens. Pp. 9-13.
5. La Corrosion des Reseaux de Distribution en Amerique. By Harry E. Jordan. Pp. 15-16.
6. Le Sterilisation par le Chlore des Eaux Residuaires Urbaines et Industrielles. By A. Albertz. Pp. 17-20.

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7. Utilisation des Phosphates Dans le Traitement des Eaux. By M. Reignier. Pp. 9-13.
8. Principaux Problemes de Limnologie Theorique et Appliquee Poses par l'Etude Piscicole des Eaux Douces. Pp. 21-24.

Restrictions On the Use of Water for Air Conditioning

Because of the consideration that has been given to the need for restrictions on the use of water for air conditioning, the following question was incorporated in a questionnaire sent to water works superintendents: "Do you restrict the use of water for air conditioning?"

Of the questionnaires returned, 854 said "No." Only 27 stated that they did apply some restrictions. However, the tone of the replies indicated a greater interest and concern in the matter than is shown by the proportion of the negative and positive replies received. Evidently a great many cities rely on metering to control excessive usage. Some of the cities made interesting comments, which are reproduced in part below:

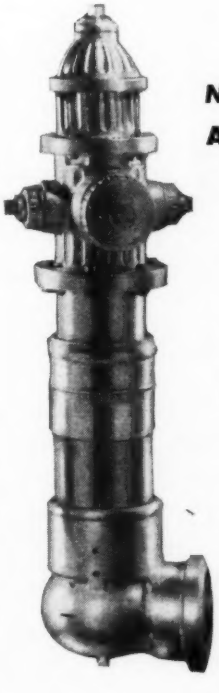
Tucson, Ariz., restricts use under certain conditions, as where wastage is apparent and when the supply is limited. Alhambra, Calif., requires that the water be used over again. Woodland, Calif., meters all such supplies. LaJunta, Colo., does not now restrict the use of water for air conditioning, but intends doing so. Manchester, Conn., says "not yet" and Southington states "we think we should prohibit." Jacksonville, Fla., says it is a "debatable question." Monmouth, Ill., restricts use unless the water is metered. Portland, Ind., says "we do not service" and Scottsburg "we are thinking about restrictions." In Iowa, Keokuk says "not yet" and Burlington "something should be done." Portland, Me., Kansas City, Mo., and Hagerstown, Md., also say "not yet."

In New Jersey, Millville restricts only "by installation of meters," and Newark has no restrictions "if metered." In New York, the problem seems to have aroused a lot of interest. Buffalo restricts by metering; Glens Falls has "not yet" applied any restrictions; Hornell requires the use of private wells; Hudson requires meters; Elmira controls air conditioning water use by regulating the discharge into the sewers; Freeport requires that the water be returned to the ground; Middletown "discourages large installations"; New York City "restricts the quantity," and Waverly has "not yet" applied any restrictions.

Lawton, Oklahoma, requires recirculation. Springfield, Minn., allows use of city water for air conditioning only "by permit, subject to disconnection in case of water shortage." Deming, N. M., "may apply restrictions" and San Antonio, Texas, is "trying to do so now." In Kenosha, Wisc., restriction depends on the ability of adjacent sewers to carry the flow.

In Ohio, Orrville and Cuyahoga Falls say "not yet" and Chillicothe adds "but may have to." In Troy, restriction is partially in effect, but on a voluntary basis. In Pennsylvania, Bradford and Bloomsburg effect control by metering; Chambersburg limits the size of the service line; Lebanon restricts service to 7 hours a day; and Philadelphia does not permit equipment using more than 10 cfm.

Richmond, Va., in 1945 issued an order prohibiting the use of water for new air conditioning units unless such units were equipped with economizers. In 1947, this order was amended to permit use of water in new installations if the rated capacity does not exceed 5 tons.



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Airport Operational Safety

(Continued from page 27)

an accident which occurred in 1945 could, with but minor variation, describe any of them:

"A night approach was overshot presumably due to a small amount of local stratus clouds in the approach path which put the pilot temporarily on instruments. The resulting attempt to go around was poorly executed inasmuch as flaps were not retracted quickly enough nor sufficient power applied when first needed and the plane settled onto a lake surface about ½ mile beyond the airport."

Missed approaches usually mean that the airplane was either not properly lined-up with the runway or was too high *to effect a landing in the space available on the airport.* Runway lengths available at the airports where the four missed approach accidents occurred varied from 4,000 to 6,000 feet but in *no case* was a *cleared, graded area* available beyond the end of the landing runway to provide a margin of safety against the uncertainties of weather, engine failure, or error of pilot judgment! The lesson to be learned from these accidents is that adequate runway width and length (300 feet by 6,000 feet at sea level for domestic airline operation) must be provided *plus* a cleared, level, sodded area beyond the runway of as great an extent as possible!

Overshot Landings

Although less dangerous to human life, accidents resulting from overshot landings, are more common than from missed approaches. Eleven crashes resulted from overshot landings during the two-year period studied and caused four fatalities, 15 serious injuries and 33 minor injuries to crew and passengers. Two of the airplanes were destroyed and nine were extensively damaged. Again, these eleven accidents are so similar that in describing one, you have described them all. A typical summary from the Civil Aeronautics Board records states:

"On instruments, flight cleared to land during overcast and worsening conditions, surface wind about 5 mph SW. In approach, following break-through, plane observed high with excessive airspeed. Contacted ground at runway intersections, continued tail high, veered left, ran off runway and through wire fence into creek bordering airport."

Overshot landings are caused by (1) the pilot making contact with the runway too far down the runway to be able to stop on the remaining pavement, (2) the runway being too short to permit stopping without running off the end of the runway, and (3) failure of brakes, preventing the stopping of the airplane before passing the end of the runway. Note that this type of accident, like missed approach accidents, could almost certainly have been avoided had adequate runway length been available *plus* a cleared, graded, sodded space beyond the end of the landing runway approximating in extent the length of the runway itself!

Undershot Landings

Still another type of landing accident is the undershot landing. During 1945 and 1946 accidents of this type caused two fatalities, three serious injuries and eight minor injuries to passengers and crew. Two of the airplanes were destroyed and two were severely damaged. Undershot landings most frequently result from the mental hazard of landing on a runway known to be short and not provided with a cleared space at

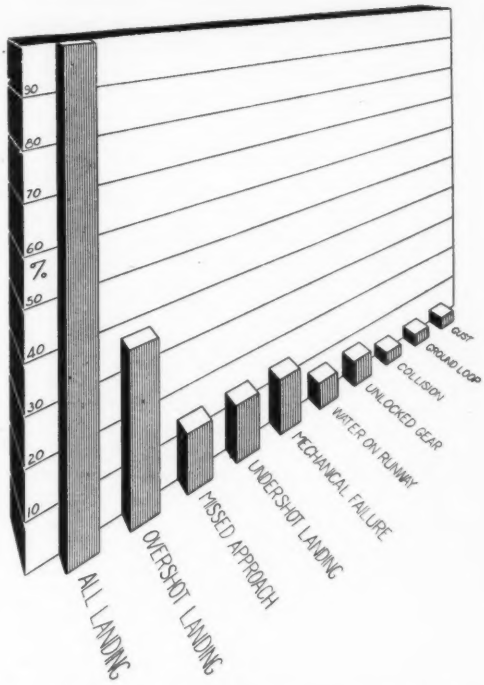


Fig. 3. Breakdown of landing accidents by per cent. Scheduled domestic passenger lines, 1930-44.

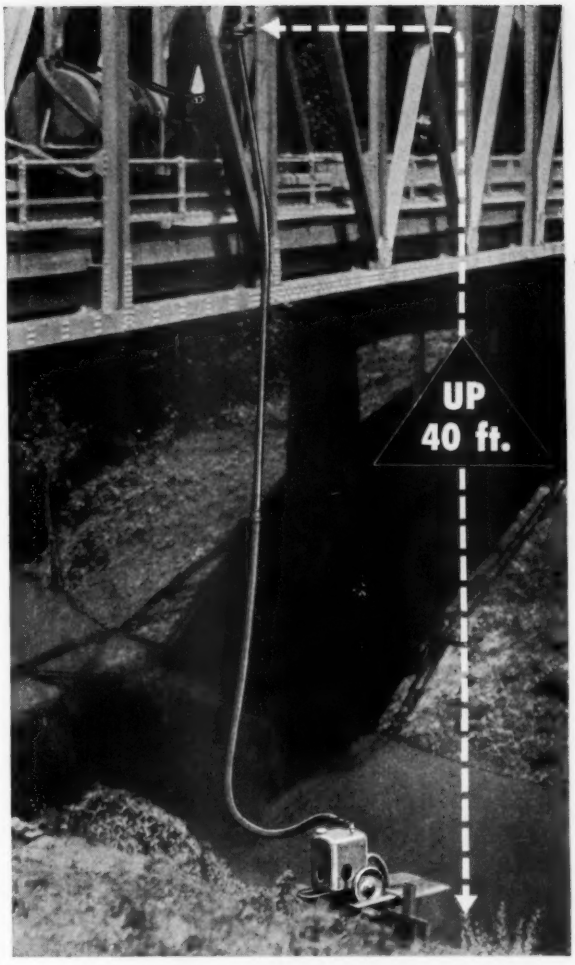
the far end of the runway for emergency use. In trying to hit the end of the runway "on the nose," for fear of overshooting, the overanxious pilot will reduce power and speed too soon and not realize his difficulty until too late for the application of power to permit the airplane to reach the runway. Certainly adequate runway length and sufficient emergency area at the far end of the runway will go a long way toward reducing the mental hazard of an overshot landing and should materially reduce the danger of undershooting.

Overanxiousness on the part of the pilot in attempting to take-off from a short runway resulted in another accident. The pilot pulled the airplane into the air in a stalled attitude before attaining a safe flying speed, lost control and the airplane bounced on the runway, alternately scraping the left and right wing tips. Here, once again, sufficient runway length would have prevented an accident that seriously damaged a transport airplane.

In addition to the landing accidents described, two airplanes sustained major damage in landing by water or slush being thrown against the airplane by the landing gear. This emphasizes the necessity of providing proper drainage for all landing and take-off areas.

Another serious landing accident occurred when the pilot misunderstood the instructions from the tower, landed on the wrong runway and during the landing roll, collided with an Army transport taking off on an intersecting runway. Although this type of accident does not frequently occur, the danger will continue to exist as long as airports are laid-out with intersecting runways. By designing the airport without intersecting runways and taxiways, landing and take-off collisions can be completely eliminated.

Of the accidents occurring during taxi operations, collision with other aircraft occurs most frequently.



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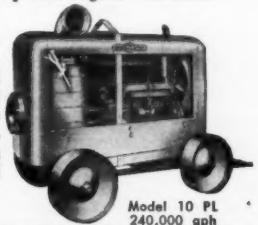

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Four such accidents occurred during the last two years and all eight airplanes were extensively damaged, although no fatalities resulted. To eliminate collisions during taxiing, it is imperative to establish a simple traffic pattern with non-intersecting taxi lanes. Smooth ground traffic flow is even more important on airports than it is on highways because wing tips extending forty to one hundred feet to each side of the pilot make it very difficult to judge clearances and maneuvering space required.

Taxiing and Other Accidents

Collision with ramp equipment during taxiing resulted in damage to three airplanes. To avoid collision with ramp equipment, the loading and servicing facilities must either be flush with the loading apron or so constructed that they may be kept completely out of the airplane maneuvering area until needed and then be swiftly and accurately positioned to provide the necessary service. Adequate lighting, so planned as to avoid confusion, must be provided at the terminal ramp. Careful layout of the terminal facilities as well as the airport itself is needed to fulfill these requirements.

Detailed study of the two year accident record of the Civil Aeronautics Board has shown that more than two-thirds of all landing, take-off and taxi accidents could probably have been avoided (see figure 4). *Over 38% of all airline accidents* might have been prevented! Thirty-four lives might have been saved! Forty-four serious injuries to individuals might have been prevented! Eight transport airplanes might not have been demolished! Twenty-one transport airplanes might not have been damaged! *That is the record!*

One of the most tragic accidents in aviation history occurred on May 27 of the past year at LaGuardia Field, New York. Forty-three persons lost their lives in an accident that almost certainly could have been avoided had adequate take-off runway length been available. Investigators of the Civil Aeronautics Board found the probable cause of the accident to be * * * "the inability of the pilot to actuate the controls due to the gust lock being on, resulting in the pilot's decision to discontinue the take-off at a point too far down the runway to permit stopping within the airport boundary." The CAB report on the accident further finds that "After application of brakes the airplane skidded for a distance of 800 feet to the end of Runway 18, and 900 feet beyond before coming to rest. It was almost immediately enveloped in flames. * * * Runway 18 at LaGuardia, 3530 feet long, has a gradient of 1 to 300, and has obstructions 32 feet high within 150 feet of the south end." It is almost certain that the accident would have been avoided if the take-off had been attempted on a runway of 6,000 feet in length. Brakes were applied after using 2,730 feet of runway which would have left 3,270 feet of runway in which to come to a stop—2,370 feet more than was required after bouncing over a highway!

New airliners, with their higher approach and landing speeds, are the result of a gradual evolution in airplane design to give higher speed in air transportation with safety and economy. So too, the airport must evolve to keep pace with the evolution in airplane design. As new airliners increase in number and size, it will become more and more imperative that airport facilities keep abreast of airliner development or our improving accident record for which so many have striven for so many years will stop improving and retrogression will set in.

The unidirectional runway airport (see "Rational Airport Planning—the Unidirectional Runway Air-

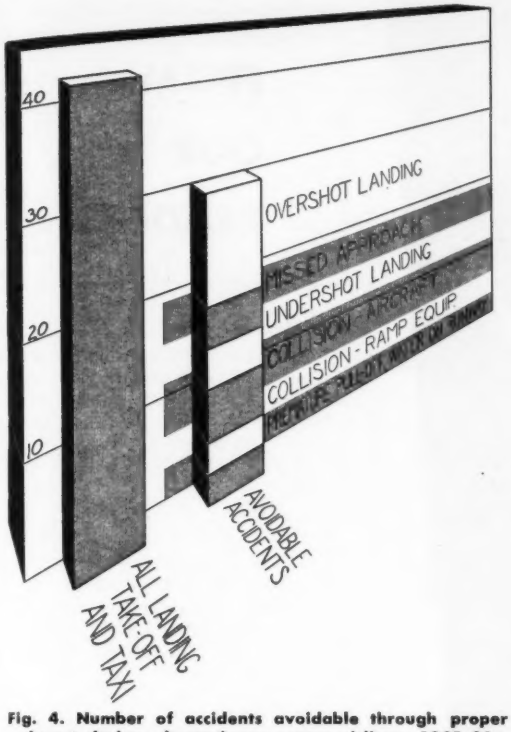

Fig. 4. Number of accidents avoidable through proper airport design, domestic passenger airlines, 1945-46.

port," *Public Works Magazine*, November 1947) provides the safety features that have been shown to be required to reduce markedly the danger of accidents at the airport. Had this type of airport been available at the site of each landing, taxi and take-off accident occurring in scheduled air transportation during the calendar years 1945 and 1946, 38% or *more than one-third of all accidents of all types* might have been avoided!

The unidirectional runway airport (see figure 5), with 6,000 feet of runway available for both landing and take-off (or 12,000 feet of runway for take-off in the case of the international airport) provides enough runway length to assure the pilot that the take-off or landing operation can be carried on with safety. Since landings will always be made on the right-hand runway, the ultimate development of this airport makes available an additional 6,000 feet of cleared, graded, sodded airport for emergency use. This extra margin to allow for vagaries of weather, mechanical failure, or pilot error can be attained in no other way without making land areas so large as to be prohibitive.

Easy and effective drainage; lack of intersecting runways; segregation of landing and take-off operations; unusually simple taxi patterns; adequate landing and take-off runway size; plus ample emergency landing area, all combine to make the unidirectional runway airport safe—safe for the community, safe for the airlines, and safe for the public!

In closing, it should be mentioned that although some persons have expressed the fear that safety will be reduced on the unidirectional runway airport due to a slight increase in the number of low-velocity cross-wind landings and take-offs necessitated, not a single accident was caused during the two-year period studied by landing in a cross-wind. That is the record in spite of the fact that some of our busiest airports are so poorly laid-out that landings in cross-winds are the rule rather than the exception!

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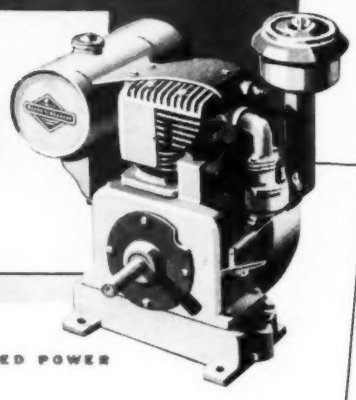

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FROM OUR READERS

Small Water Plants:

The Editor.—Please send me information about manufacturers of equipment for small water treatment plants. I have in mind the kind of plant that can be used to serve an isolated lock and dam where the personnel is apt to be about 20 people.

F. F. ESCOFFIER
PO Box 1169, Mobile, Ala.

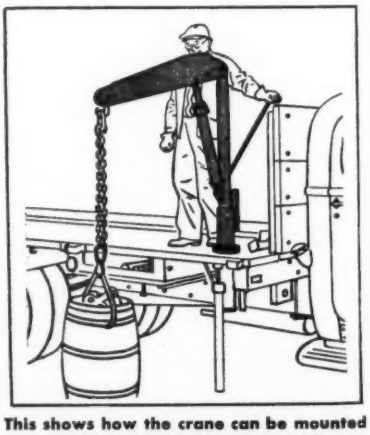
(Ed. Note: We sent Mr. E. some data and referred him to Ala. Power Co. & TVA, which have the same problems; also the State Bd. of Health of Ala. Our readers may have additional information to send.)

Handy Crane:

The Editor.—We were very much impressed by the article on page 38 of your February issue "Handling Heavy Water Department Articles." We would appreciate information as to the make and manufacturer of the 1-ton hydraulic crane described.

JAMES RENNICK, JR.
Washington, Mo.

(Ed. Note: We wrote L. O. Porter, Manager of the Marion, Ohio, Water Co., and he says, in part: "In these days of high labor costs as well as manpower shortages, it is necessary to provide mechanical means for doing as many jobs as possible. Economy is mandatory, and safety for employees should be a first consideration. We have many fire hydrants which must be brought into the shop for repairs; removing



This shows how the crane can be mounted on a truck. End mounting might be better for water departments.

and reinstalling these are hazardous. We could not tie up a truck for crane use only and the mast-height of all other cranes we investigated was too high to get the truck in the garage. We feel we were fortunate in locating this 1-ton hydraulic crane. It is made by Ruger Equipment Co., Inc., 408 Leader Bldg., Cleveland, O., and it cost us $317.50. We believe it is one of the best investments we have made. One of its main advantages is its ability to swing the boom 180°, which permits loading and unloading from the truck. However, because of the low mast-height, articles cannot be lowered from the truck to a trench; two hitches are necessary to do this."

Our Face Is Red :

The Editor.—I would like to have a copy of the March 1947 issue of PUBLIC WORKS for my files. I have some boys on "Job Training" and the articles in the January and February, 1947, issues are the best outlines I have seen on the subject. I would like to have the third article which deals with sub-bases, bases and certain types of surfacings. I would like to say that PUBLIC WORKS is the most informative technical magazine, for all phases of engineering, that I receive.

W. J. CLARKE
Georgia State Highway Dep't.

(Editorial Apology: We didn't think that anyone would get around so fast to wanting that third installment, and even though we promised it for an "early" issue, we haven't gotten around to writing it yet. It is now scheduled for "near" future preparation.)

Codes:

The Editor.—I should like to inquire whether plumbing and mechanical codes are published by you as samples for further study. During the past month we have considered the writing of such codes and we would appreciate whatever information or references you can give us for furthering our study.

D. N. VALK, Chairman,
Board of Public Works,
Maryville, Mo.

(Ed. Note: Will our readers send copies of appropriate codes to Mr. Valk? We do not publish material of this type. Thank you.)

A Fine Street Plan Report

The Department of Highways of the State of Louisiana, Baton Rouge, La., has sent us a beautifully prepared street and highway plan for Alexandria, La., prepared by H. W. Lochner & Co., Chicago, Ill. This plan is the result of a careful analysis of existing traffic facilities, origin-destination flows and available finances. It is a fine job; and how different "Alex" looks from the days of World War I when yours truly was there.

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IHC 100-hp. Diesel Engine

This is the second new diesel announced this year by IHC. This is a 6-cylinder, 100-hp., and is known as the UD-16. It is designed to use a variety of low-cost fuels, including No. 3 fuel oil. It is intended for rock crushers, gravel plants, saw mills, motor graders, cranes and shovels, air compressors, pavers, tractors, and similar uses. *International Harvester Co., Chicago, Ill.*

Emery Aggregate for Floors.—This bulletin gives the recommendations of the Portland Cement Association for good aggregate for floors, with strength analyses, and stresses the use of natural emery for floors that must withstand hard wear. Bulletin 701. Walter P. Maguire Co., Inc., 330 West 42nd St., New York 18, N. Y.

Portable Centrifugal Pumps.—Four new self-priming portable pumps designed for utility maintenance work are described in a 4-page bulletin which contains performance tables and size and weight data. These are 1½ to 3-inch pumps. Ask for Bulletin U-47. Marlow Pumps, 238 Greenwood Ave., Ridgewood, N. J.

Handling Aggregates. — "Link-Belt Machinery for Handling and Preparing Sand, Gravel and Stone" is the title of a new 64-page book covering all types of elevators and conveyors; screens; washing and dewatering units; shovels; cranes; draglines, and other equipment. Many photographs and diagrams; data on how to lay out a material handling or washing job. Helpful to any concerned with aggregate. Ask for Book No. 2126. Link-Belt Co., 307 N. Michigan Ave., Chicago 1, Ill.

Extra-Strength Clay Pipe. — This folder gives the dimensions of the new extra-strength clay pipe, sizes 4-in. to 30-in.; also comparative supporting strength of standard and extra-strength pipe for different types of bedding; and minimum crushing strengths. Clay Sewer Pipe Association, Inc., Huntington Bank Bldg., Columbus, Ohio

Rate of Flow Indicators.—Describes and explains application, principle and operation of Style O rate of flow indicators. Infilco, Inc., 325 West 25th Place, Chicago, Ill.

Crushing and Screening plants, including primary and secondary rock and gravel plants, are described in Bulletin 574 by Pioneer Engineering Works, Minneapolis, Minn.

Batching Plants are illustrated and described in four folders describing 80, 100, 150 and 300-ton units. All models have weigh-batching with central cement compartment, one-man operation, portability and flexibility. Noble Co., 1860 7th St., Oakland 7, Calif.

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Research, Investigations and Reports

Salary and Wage Practices of State Highway Departments.—This 51-page booklet (Highway Research Board No. 9) contains factual data from 43 state highway departments. Material includes a summary of findings and conclusions, a discussion of the existing shortage of engineers in these departments, a general appraisal of existing salary plans, analysis of the data and general recommendations, with suggested salary increases. Write the Highway Research Board, Washington, D. C.

Design of Flexible Pavements Using the Triaxial Compression Test.—This method of testing soils and related materials, and the application of the test data to the design of flexible pavements, as developed by the Kansas State Highway Commission, are presented, with sample calculations, derivations, tables and charts. 63 pages. Highway Research Board, Washington, D. C.

Airport Runway Evaluation in Canada.—Contains chart of thickness design curves for a wide range of wheel loads, designed to indicate the required thickness of granular base for highways and for different parts of airport runways, based on plate bearing tests and on cone bearing, Housel penetrometer, California bearing ratio and triaxial compression. 138 pp. Highway Research Board, Washington, D. C.

Safety Directory.—The 1948 edition of Best's Safety Directory has been published. This 494-page volume shows what safety devices or products to use for specific hazards, how to use them and where to get them. The indexing and subject-grouping method used is convenient, and with the many illustrations, makes the book exceptionally easy to use. Write Albert M. Best Co., 75 Fulton St., New York 7, N. Y.

Federal Works Agency.—The eighth annual report, for 1947, is a summary of reports of the three constituents of the Agency—the Public Buildings Administration; the Public Roads Administration; and the Bureau of Community Facilities. 47 pages. Separate reports of each of the three subdivisions of the agency are available elsewhere. This report is 20¢ from the Sup't. of Documents, Washington, D. C.

Ohio Conference on Sewage Treatment

The 1948 annual meeting of the Ohio Conference on Sewage Treatment will be held in Dayton, June 23, 24 and 25, with headquarters at the Dayton-Biltmore. G. A. Hall, State Dep't. of Health is Secretary.

Kentucky-Tennessee Section AWWA

The Kentucky-Tennessee Section of the AWWA will meet at Chattanooga, Tenn., Aug. 23-25, 1948. G. R. Kavanagh, Wallace & Tiernan Co., Knoxville, Tenn., is section chairman.

Southwest Section, AWWA

The 1948 meeting of the Southwest Section, AWWA, will be held in Galveston, Texas, Oct. 10 to 13. L. A. Jackson, Robinson Memorial Auditorium, Little Rock, Ark., is secretary-treasurer.

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All About Crawler Track Lubrication

2—Full information on what to do and how to do it, with grades of lubricants, is contained in the June, 1947, issue of "Lubrication," published by The Texas Co., 135 E. 42nd St., N. Y. Address A. R. Dunphy.

Perforated Materials — Any Size or Shape of Hole

3—If you want plain or funny-shaped holes in metal sheets, name your hole and the kind of metal and you will find it in this catalog. We never knew there were so many shapes of holes available. Ask for Catalog 62. Harrington & King Perforating Co., 5655 Fillmore St., Chicago 44, Ill. The book contains lots of handy tables, too.

How Elevated Water Tanks Can Save on Operating Costs

4—Beautiful new booklet on Horton elevated steel water tanks suggests ways to reduce pumping costs, increase capacity of systems, maintain uniform pressure, etc. Illustrates 7 models of welded, ellipsoidal-bottom, elevated steel tanks in full color. Write Chicago Bridge & Iron Co., 2115 McCormick Bldg., Chicago 4, Ill.

Data Book on Universal Concrete Cribbing

5—Shows typical sections for designing walls, pictures many applications, specifications, etc. Get the facts today about this economical reinforced concrete cribbing. Universal Concrete Pipe Co., Dept. PW, 297 So. High St., Columbus 15, Ohio.

Flow Meters with Many New Features

6—The new "Propeloflo" meter for main-line metering introduces many new features you will want to look into. Streamline Venturi design results in exceptional accuracy. Send for latest bulletin today. Builders Providence, Inc., 16 Codding St., Providence 1, R. I.

Metals That Will Resist Almost Any Chemical

7—Non-corrosive equipment for handling chemicals. Duriron Durichlor and Durimet, resistant to all chemicals used in water treatment. Used for pumps, valves and fittings generally. Described in recent booklet issued by The Duriron Co., Inc., Dept. PW, 17 East 42nd St., New York, N. Y.

Grating for Bridge Flooring Sewage, Water Plants, etc.

8—For complete data on the uses and advantages of open steel mesh pavement for bridges, airport runways, catch basins and walkways, floors and ladders in sewage treatment and filtration plants, write for catalogs from Irving Subway Grating Co., Inc., 50-09 27th Street, Long Island City 1, N. Y.

A New Answer to Some Old Waterworks Problems

9—That is what they call "Hypo-Chlorination of Water," a 75-page illustrated discussion of this live subject, in a booklet packed with helpful information. For your copy, address: Mathieson Chemical Corp., Dept. PW, 60 E. 42nd St., New York 17, N. Y.

Latest Facts on Marlow Pumps for Utility Use

10—Attractive new booklet U-47 tells all about Marlow centrifugal utility pumps in 1", 2" and 3" sizes. Gives test performance data. Featherweight aluminum units. If you are also interested in larger pumps, ask for G-47 too. Marlow Pumps, Dept. PW, Ridgewood, N. J.

Special Light-Weight Rock Drill

11—A 4-page bulletin describes the Cleco self-rotating, lightweight (9 lbs.) hand held pneumatic drill that is convertible to a chipping hammer by removal of one part. Bulletin HD-1147, Cleco Division, Box 2119, Houston, Texas.

Useful Data About Packaged Generators

12—This excellent 16-page booklet describes "packaged regulectric generators" and gives data on selection for service, approximate power requirements, tables for wire sizes and other information. Ask for Vol. 8, No. 3a of the Synchronizer. Electric Machinery Mfg. Co., 821 2nd Ave., S., Minneapolis 13, Minn.

Mixers on the Move

13—This describes the use of FWD trucks for mounting ready-mixed concrete bodies. FWD truck mixer capacities range from 2 to 5½ cu. yds. Four Wheel Drive Auto Co., Clintonville, Wisc.

What Engineers Want to Know About Butterfly Valves

14—A 60-page hard-cover book with gives detailed descriptions and specifications. This book is designed for engineers with emphasis on actual blueprint reproductions. Ask for Catalog A. Henry Pratt Co., 2222 So. Halsted St., Chicago 8, Ill.

All About Cement-Mortar Lining of Water Mains

15—Here, in a really beautiful booklet, is practically everything you need to know about this method of lining mains in place—the needs, methods, and results that will interest you. Centriline Corp., Dept. PW, 140 Cedar St., New York 6, N. Y.

Pipe and Leak Locator

16—Complete information on a compact pipe, cable locator and leak detector, and also information on servicing and care for electrical instruments is available by writing the Nilsson Electrical Laboratories, Inc., 103 Lafayette St., New York 13, N. Y.

Need Metal Surface Protection?

17—Metal Surface Protection is covered in a 12-page booklet describing properties, advantages, typical uses and application of Dum Dum. Arco Co., 7301 Bessemer Ave., Cleveland 4, Ohio.

Due to printing stoppage in New York City it has been necessary to curtail or omit certain features in this issue.

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